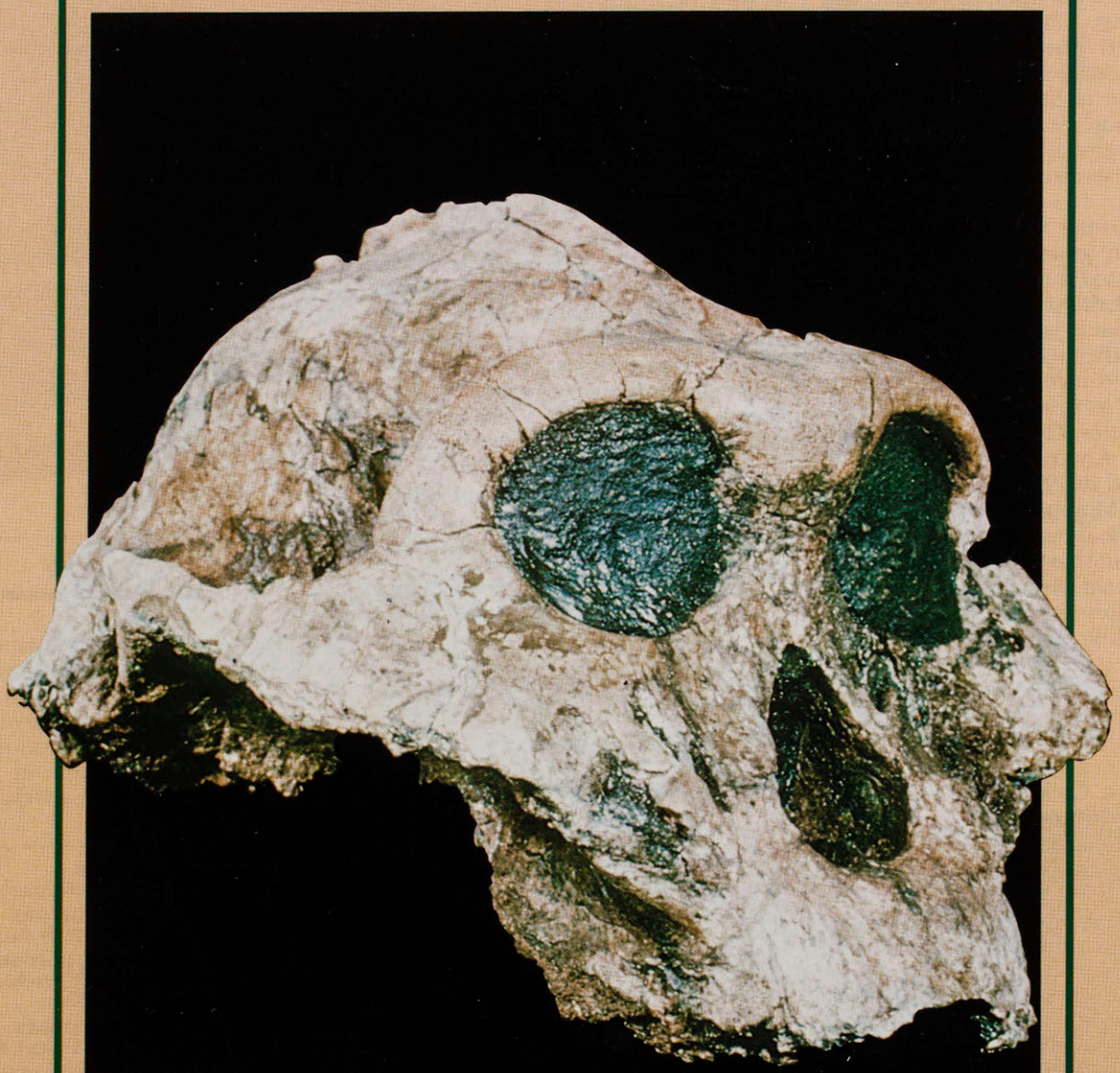
# TERRA

THE NATURAL HISTORY MAGAZINE OF THE WEST

VOL. 20, NO. 4/SPRING 1982



## PALEONTOLOGY ON FOUR CONTINENTS

# A Step Forward

## New Director Named

In the last issue of TERRA I reported to you that in spite of the sudden resignation of Dr. William B. Lee as Director of the Museum, the Museum was going strong because of the energies, expertise and dedication of the Museum staff and its various Boards. I am now extremely pleased to report that the Museum has taken a major step forward with the appointment of Dr. Craig C. Black as our new Director. The appointment, to become effective September 1, 1982, was recently announced by the Los Angeles County Board of Supervisors, following the unanimous recommendation of the Board of Governors and with the wholehearted endorsement of the Museum staff and Boards.

Dr. Black comes to the Museum after serving seven years as Director of the Carnegie Museum of Natural History in Pittsburgh, Pennsylvania. While at Carnegie, Dr. Black was instrumental in securing significant outside funding from community sources—an impressive achievement in times of increasing economic pressures. He is currently President of the American Association of Museums and in 1974 was appointed to serve on the Museum Advisory Panel to the National Endowment for the Arts. He is a member and past president of numerous professional associations, including the Association of Science Museum Directors and the Society of Vertebrate Paleontology.

Born in 1932 in Peking, China, of American parents, Dr. Black initially planned to follow in the footsteps of his physician father. After earning his B.A. from Amherst College in 1954, he was appointed a Simpson Fellow at Johns Hopkins Medical School; however, after a year he abandoned the idea of a medical career and returned to Amherst where he received an M.A. in 1957. In 1962 he was awarded a Doctor of Philosophy degree from Harvard University.

Prior to and after receiving his Ph.D., Dr. Black was affiliated with the Carnegie Museum, first as Associate Curator and then Curator of Vertebrate Fossils. In 1970 he was named an Associate Professor at the University of Kansas, and in 1972 was appointed Director of the Museum and Professor of Geosciences at Texas Tech University—returning in 1975 to the Carnegie Museum as Director.

Dr. Black's personal fascination and professional involvement with vertebrate paleontology spans more than two decades; and even in his capacity as Carnegie Museum Director, he continued an active role in research activities. Field work conducted for a number of years in countries such as France, Tunisia, Kenya, South Africa, Algeria, Greece and the United States led to the publication of numerous research reports and magazine articles, several pending publication.

Dr. Black has been described as the "ideal combination of scientist, administrator and community leader." His enthusiasm and vitality are contagious—and the staff and I look forward to working with him in setting and achieving new goals for the Natural History Museum. I hope you will all join with us in this enthusiasm. A more complete profile of Dr. Black and his family will be presented in the Summer 1982 issue of TERRA Magazine.

Leon G. Arnold
Acting Director

***It is TERRA's good fortune to have assembled four exceptional essays, each dealing with a different aspect of paleontology, each based on work done on a different continent.***

***All four articles were written by scientists associated with the Natural History Museum of Los Angeles County—a tribute to the exceptional diversity and depth of work in progress at the Museum.***

***The great age of our planet, the very beginnings of mankind, the migratory wanderings of man and beast, the rise and fall of land and sea, the patient, painstaking investigations of modern man in his efforts to learn more about the earth's past—all these are touched on in this issue of TERRA.***

**The Editors**

# Curators & Collections

## Lansdowne Bird Paintings

Twenty original gouache paintings from J. Fenwick Lansdowne's *Birds of the West Coast,* Volume Two, are on exhibit in the Changing Gallery outside the Museum's permanent Bird Hall. The paintings combine an artist's vision with a scientist's devotion to detail.

Like Audubon before him, Lansdowne is a painter of consummate skill, and his goal is the accurate representation of a specific bird in an aesthetically pleasing manner. Focusing on the birds which inhabit the Pacific Coast between his native Canada and Baja California, the gouaches capture the plumage, structure and characteristic motion of such species as the Common Merganser, the Western Sandpiper, the Black-necked Stilt and the Brown Pelican.

## Shells on Display

The Malacology Section is displaying an exhibit of large colorful shells of the

(continued on page 31)


# TERRA

THE MEMBERS MAGAZINE OF
THE NATURAL HISTORY MUSEUM ALLIANCE
OF LOS ANGELES COUNTY
VOL. 20, NO. 4/SPRING 1982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## Cover

This virtually complete male *Australopithecus boisei* cranium is between 1.4 and 1.6 million years old and was discovered by Richard and Meave Leakey in 1969. *A boisei* is common throughout the Early Pleistocene portion of the Koobi Fora sequence (see first article).


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# Script for A Great Museum Adventure

**TIME** June 6, 1982
10 a.m. to 4:30 p.m.

**LOCATION** Natural History Museum
Exposition Park

**CAST OF CHARACTERS**

Museum members, families and friends, craftsmen, dancers, musicians, storytellers

**ACTION** A glimpse of the Old West...
Sheepshearing, blacksmithing, horseshoeing, trick roping

The lively performance of old-time crafts...
Spinning, quilting, woodworking, weaving, scrimshanding, lacemaking, basketry, long rifle and powder horn making, doll making (apple-head, porcelain, Japanese) and much more

The delight of music and dancing...
Square dancing on the green, mandolin players, Murray Korda and the Monseigneur Strings

The fun of exploring the Museum and discovering living exhibits that walk and talk...
Featuring the "Great Museum Game" in which gamecards and prizes will encourage fairgoers to investigate the Museum in a treasure hunt

**SPECIAL EFFECTS**

Craft Fair Membership Premiums...
Tell your friends! For the purchase of a Museum Alliance membership, NEW OR RENEWAL, during the day of the Craft Fair the following premiums will be offered:

**$ 15** STUDENT Full Time (with ID) or Senior Citizen 62 and over (with ID) Choice of Museum Logo T-shirt or lapel pin.

**$ 25** ACTIVE Choice of Museum Logo totebag, scarf, T-shirt or lapel pin.

**$ 50** CONTRIBUTING A very special behind-the-scenes tour of the Natural History Museum for a family or small group (time and date to be set by mutual agreement) PLUS a choice of Museum Logo belt buckle, tie, scarf, tote bag, T-shirt or lapel pin.

**$100** PATRON A once-in-a-lifetime ride in an antique car for you and your immediate family with the Museum curator of automobiles, Jim Zordich. The car will be one built between 1900 and 1910. If you live inside Los Angeles County, Mr. Zordich will bring the car to your home and drive you past admiring friends and neighbors (time and date to be determined by mutual agreement) PLUS any one of the Museum Logo premiums offered in other categories.

**YOU MUST PURCHASE YOUR MEMBERSHIP AT THE CRAFT FAIR TO RECEIVE THESE PREMIUMS.**

# The Search for Early Man in Northern Kenya

by JOHN M. HARRIS

*No vehicles are permitted on the exposures and so even the heaviest specimens have to be hand-carried to the vehicles. Here the "hominid-hunters" retrieve a complete 1.5 million-year-old skull of the elephant-like* Deinotherium *which weighed 400 lbs.and is now plastered for protection on the journey back to Nairobi. The co-leaders of the project, Kamoya Kimeu and Richard Leakey, are on the extreme left and extreme right.*

The East African Rift Valley system forms a scar, running from the Red Sea to Mozambique, that is prominent enough to be seen from the moon with the naked eye. Ancient river and lake sediments preserved along its length date back as much as twenty million years and harbor an incredible wealth of fossil material. These fossils chronicle the past migrations of animals to and from Eurasia, the gradual establishment of the modern African faunas, and the constantly changing climates of the past. Volcanic activity associated with the formation of the rift system has contributed lavas and ashes that enable such events to be precisely dated.

Forming part of these ancient faunas are the fossil remains of our earliest ancestors and their close relatives. During the past two decades many such specimens have been recovered through the skillful effort of international expeditions to different parts of the rift valley. The result has been a significant contribution to our understanding of the origin and evolution of man. Individual discoveries have generated discussion and controversy in the international news media. As the elder Pliny remarked nearly two thousand years ago, "Ex Africa semper aliquid novi" (...out of Africa there is always *something* new)!

One of the most important localities lies to the east of Lake Turkana (also known as the "Jade Sea") on the border between Kenya and Ethiopia. Shaped rather like the leg of a dog, Lake Turkana is over 160 miles long and averages sixteen miles wide. From the north it is fed by the Omo River which drains the Ethiopian Highlands. Smaller rivers that are dry for most of the year converge from the east and west. The lake has no outlet and is saline. Here for many centuries the local people (Turkana on the west side of the lake, Dassenetch and Rendile to the east) have gone about their daily activities oblivious of the history beneath their feet.

The potential importance of the ancient sediments surrounding the lake has been recognized for many years. Specimens recovered from the western side include a (reworked) dinosaur bone and the skull of a freshwater whale. More recently, however, research in the region has been stimulated by the search for the remains of early man, and for the past fourteen years effort has been concentrated on rocks of between one and four million years in age which are exposed along the northeastern shore of the lake. The Koobi Fora Research Project, coordinated by the National Museums of Kenya and involving scientists from more than a dozen different countries, has recovered nearly 200 hominid (= human) fossils, some of them spectacularly complete, and has investigated the associated fossil floras and faunas and early stone industries.

Lake Turkana was first located in 1888 by Count Samuel Teleki who named it Lake Rudolf after the then Archduke of Austria. In 1973 it was renamed Lake Turkana by the first president of Kenya, Mzee Jomo Kenyatta. Prior to 1967 no detailed investigation of the region east of the lake had been undertaken — in part because of its remoteness, in part because the east side provided a corridor along which cattle rustlers, sometimes heavily armed with modern weapons, plied their trade back and forth across the border between Kenya and Ethiopia. In 1967

Richard Leakey, Director of the National Museums of Kenya, visited the area briefly and ascertained its fossil-bearing potential. The following year he mounted a longer exploratory expedition to the east side of the lake to which, much to Richard's chagrin at that time, I was invited to participate by his father, the late Louis Leakey!

That first (1968) season, accompanied for protection by an armed platoon of the General Service Unit (Kenya's paramilitary force), a half dozen of us made a complete sweep of the region to reconnoiter its geology and paleontology. As might be expected from a lake that had periodically fluctuated in size through time, the geology was complex and complicated further by faulting that had accompanied the development of the Eastern Rift Valley. Fortunately the ancient river and lake sediments were intercalated by a number of tuffs (volcanic ashes) which could be used as marker beds from which to determine the geological succession; these tuffs were later used to obtain radiometric dates for the sequence. By the end of the expedition we had located a number of extremely rich fossiliferous localities and had found a handful of rather fragmentary hominid fossils.

Encouraged by these preliminary findings, a second expedition was mounted the subsequent year, resulting in the discovery of additional hominid fossils, including a relatively complete robust australopithecine skull, and a site that yielded simple Oldowan-type stone tools. Thereafter the project expanded rapidly; geologists, paleontologists and archaeologists were recruited from different institutions in Africa, Europe and North America, and a permanent field headquarters was established on the Koobi Fora sandspit (from which both the project and the locality subsequently took their names). During the ensuing decade the region was prospected intensively and yielded a wealth of fossil and archaeological material that is still in process of investigation.

The region to the east of Lake Turkana may be classified as semidesert scrubland —grassy areas adjacent to the lake giving place to *Acacia* and *Commiphora* thickets on higher ground. The only tall trees in the region line the banks of major rivers, which are in flood for one or two days each year and totally dry for the rest of the time. Low hills of gray and brown sandstone and clay denote the former extent of the lake in prehistoric time and the channels of much larger rivers that formerly drained the region. The eastern horizon is formed from the upfaulted scarps of Miocene volcanic rocks (five to twenty million years in age) that mark the present margin of the Lake Turkana basin. Across the lake to the west may be seen similarly-formed hills along the western boundary of the basin.

Because of the former cattle-raiding activities, coupled with the arid climate, the east side of the lake was only sparsely populated and, as a result, the wildlife has remained relatively undisturbed. During the course of any one field season one may encounter all the large African carnivores, reticulated giraffe, Burchell's and Grevy's zebra, herds of oryx and topi, Grant's gazelle and gerenuk, and the Somali ostrich with its brilliant blue neck and legs. The lake teems with fish, of which tilapia and Nile perch provide particularly good eating. Crocodiles are plentiful and hippos are occasionally seen. Much of the area investigated by Koobi Fora project members has now been designated the Sibiloi National Park; the purpose of the legislation was to conserve the prehistoric sites but the game animals are also covered by the protection.

The abundance of wildlife provides a very welcome bonus to field work. The living animals provide clues to how their fossil counterparts exploited the region, their dead carcasses provide comparative material to help identify the fossil bones, and by observing the way that skeletons break up and are buried one obtains a clearer insight into how the fossil material was preserved. In addition, recent lion kills provide welcome supplies of fresh meat, though care must be taken to ensure that the lions have finished with them first; one over-eager party of scientists once helped themselves prematurely to an oryx carcass with the result that the angry lions followed them back to camp and revisited them nightly for the next two weeks!

Since 1970, most of the vertebrate fossils from the region have been located and collected by the paleontological field crew of the National Museums of Kenya (informally known as "the hominid-hunters"). The crew is led by Kamoya Kimeu, co-leader of the Koobi Fora Research Project, who started his career at Olduvai Gorge working for Mary Leakey. I was part of Kamoya's team for much of this time and had the responsibility of documenting the provenance of all fossil specimens recovered from the field. Apart from myself, neither Kamoya nor any member of his team has had more than fourth grade education but all are expert in recognizing even fragmentary scraps of human fossil material; indeed their proficiency at identifying the remains of the more than a hundred fossil mammal species found in the sediments would shame most zoology or paleontology graduate students from any university in the world.

The Plio-Pleistocene fossil sediments are exposed over an area of approximately 1000 square kilometers which even now has yet to be explored fully. The main emphasis of the crew's activities is the location of fossil remains of early man; to this end most of the region is surveyed annually during the course of the two to

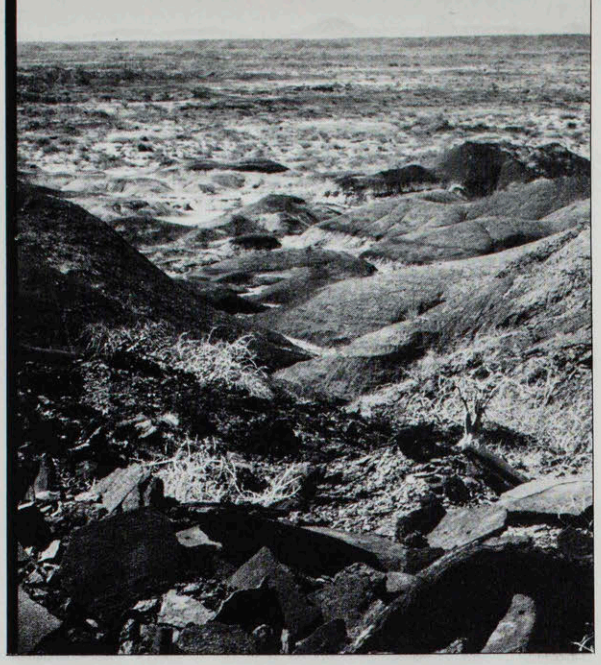
*Above: Map of East Africa to show the location of the more significant hominid-bearing localities that are located in the eastern (Gregory) Rift Valley.*

*Below: ERTS satellite photograph of northern Lake Turkana. The light-colored areas fringing the lake are Pliocene and Pleistocene sediments; the darker green areas are Miocene volcanic deposits.*

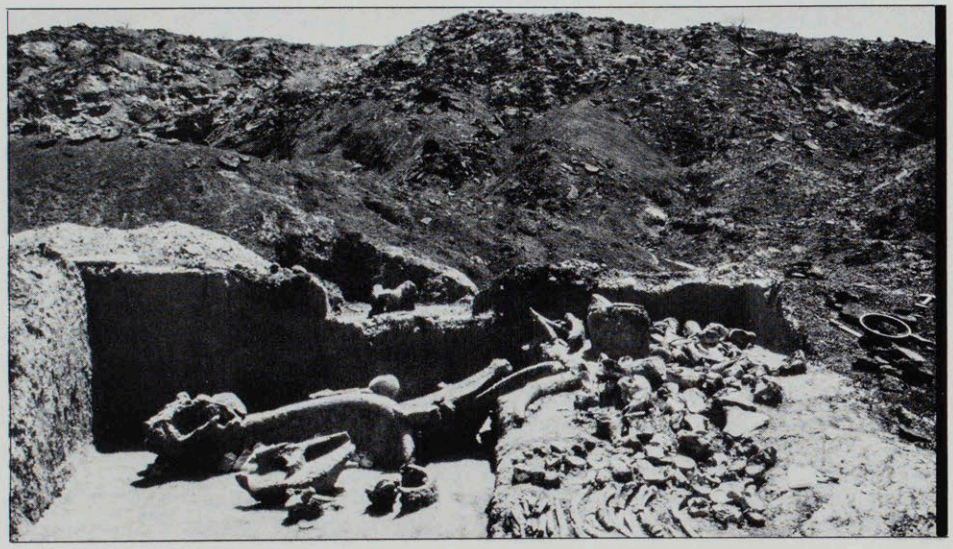
three month field season to determine if new hominid fossils have weathered out of the rocks. To attempt to cover the area in this short time imposes a very tight schedule on prospecting activities and as a result nearly all of the more than 6000 mammalian fossils that have been collected to date were recovered through surface prospecting. Usually only the more complete specimens and those potentially identifiable to species level are collected. More detailed excavations of some of the particularly rich fossiliferous beds have been undertaken by other participants in the project. Kamoya's team works largely independently and other members of the project are often only encountered during provisioning trips to the field headquarters. Small field camps are established close to the fossiliferous exposures, thereby making maximum use of daylight hours and conserving gasoline which has to be brought from Nairobi, some 400 miles to the south. From each camp, located amid the largest clump of trees in any one area, the team sets out daily just after dawn and drives to the nearby fossiliferous exposures. No driving is permitted on the exposures themselves because of the possibility of damaging important fossil material. From the vehicle, members of the team spread out, walking slowly with backs bent and eyes glued to the ground. When a vertebrate fossil identifiable to species is located, its exact position is marked on an aerial photograph and its stratigraphic level determined before it is picked up. Details of the fossil are entered into field notebooks and an aluminum tag bearing the field number of the fossil is secured by a six-inch nail to the spot where the fossil was found. Hominid fossils merit different treatment; their precise location and stratigraphic level are recorded by the prospecting team but the hominid fossils themselves remain undisturbed until they have been examined by the project's paleoanthropologists.

Between dawn and about 11:30 a.m. light conditions are ideal for finding fossils but after five hours of intense concentration in temperatures of 100°F or more, eyes become tired and the glare and temperature as the sun approaches its zenith makes observation difficult. Over the noon period the team rests for an hour or so, returning several miles to the vehicle for water, lunch and to catalog the morning's finds, and then resumes work until just before sunset. They then return to camp where the specimens are cleaned, labelled and packed for shipment to Nairobi.

Of necessity most of Kamoya's camps are located well away from the lake, which means that water for washing as well as drinking and cooking has to be obtained from temporary wells dug into the beds of the dry sand rivers. The water supply inevitably diminishes as the season progresses and is often short at the best of times. Mosquitoes, flies, scorpions and snakes provide daily irritations and there are clearly limits to the variety of menus that can be prepared from a staple diet of canned corned beef, baked beans and corn meal. Nevertheless the excitement of the search, one never knows what may be found next, persists throughout the season and is contagious; there is always stiff competition amongst the Kenyan museum staff to obtain promotion to the "hominid-hunters."



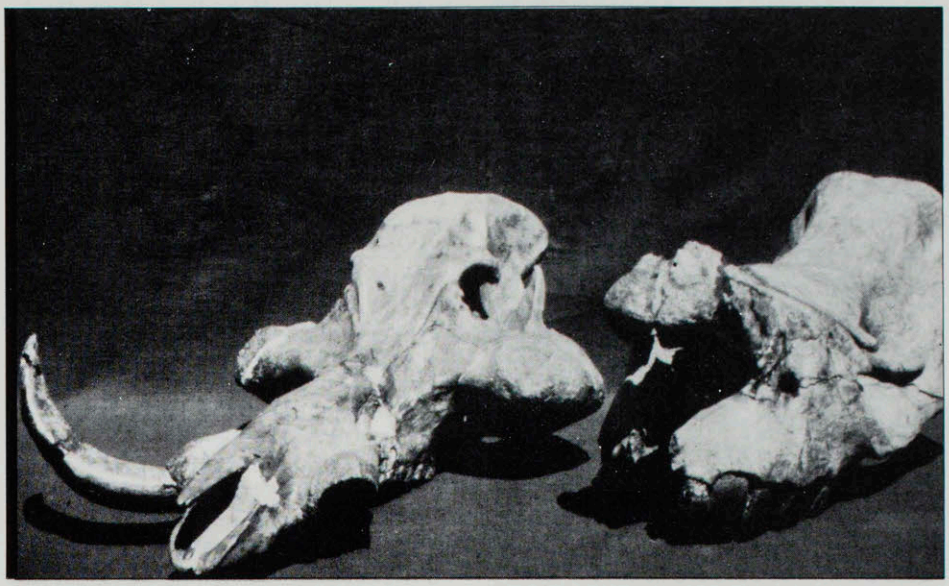
*Early Pleistocene lake sediments from the central part of the study area. The slabs in the foreground are from ancient sandbars and some are formed entirely from snail shells.*

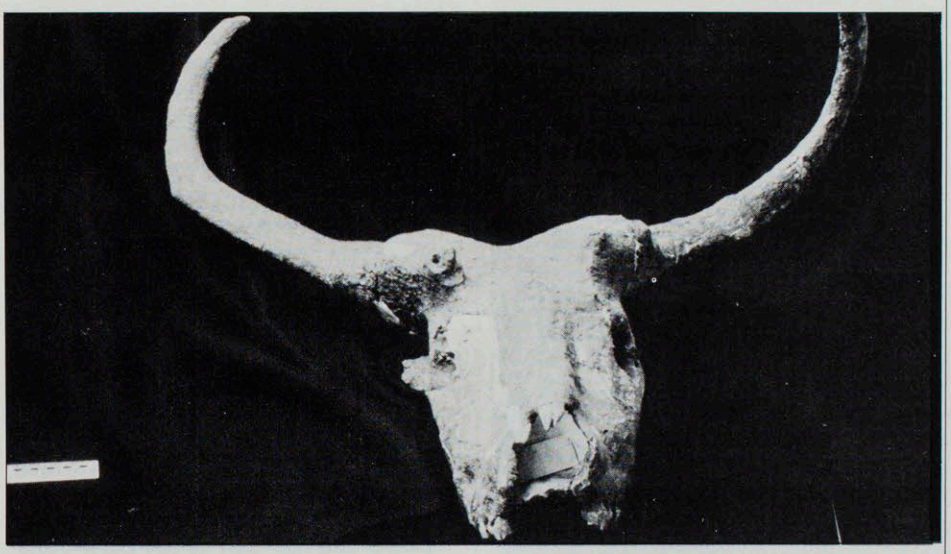


*Excavation of a fossil Indian elephant skeleton* (Elephas recki) *about 1.8 million years old. This specimen was excavated by Dr. Kelly Stuart, was studied in the field, and a museum has now been erected over the spot for visitors to the Sibiloi National Park.*

At the end of the field season the fossil material is shipped back to the National Museum in Nairobi (all but the largest specimens by light plane) where it is fully prepared, accessioned into the collections and made available for study. The relative completeness of the fossil material recovered from Koobi Fora is of great importance for the identification of other more fragmentary material from sites of similar age elsewhere in Africa, and keeps a team of six preparators frantically busy during the ensuing twelve months.

After nearly fourteen years we have a fairly accurate idea of the composition of the fossil faunas that roamed the region east of Lake Turkana between one and four million years ago, and which include the ancestors of modern African mammals as well as extinct species with no living counterparts. Both Indian and African elephants are represented in the sequence together with the extinct elephant-like *Deinotherium*. There were at least four species of zebra, a fossil ass, and several species of the three-toed horse *Hipparion*. Rhinos were uncommon but included the ancestors of both living African species. Four extinct species of hippo, one a pygmy form, were present. Camels occurred but were very rare. Giraffes were represented by three different species of true giraffe plus the long-horned but short-necked *Sivatherium*. More than forty different species of antelopes have been collected. The carnivores included lion, leopard, cheetah, hyenas, hunting dog, jackals, otters and genets as well as extinct sabre- and dirk-toothed cats. Primates were represented by a number of species of baboons, mangabey and colobus monkeys and by





*Top:* Kolpochoerus limnetes *(left) was one of the common pigs in the Early Pleistocene portion of the sequence. It shared a common ancestry with the giant forest hog, now the largest living African pig, but attained a much larger size. Fossil specimens of black rhinoceros (right) are almost identical in morphology and size to the living form but are only rarely encountered in the Koobi Fora sequence; this was the first complete fossil black rhino skull ever discovered.*

*Bottom: This specimen from Koobi Fora, about 1.6 my in age, is the only complete* Sivatherium *skull yet found in Africa.* Sivatherium *had long horns and was about the size of an African buffalo but was a short-necked relative of the giraffe.*

at least three species of hominids.

The vicinity of Lake Turkana has become progressively drier during historic time. Elephant, waterbuck and buffalo were all reported from the south end of the lake by Teleki in 1888 though these animals are no longer found there today. Geologic evidence, and that from the fossil material recovered from east of the lake, suggests that the trend towards increasing aridity has persisted for a long time. During the late Pliocene the region was appreciably cooler and more humid than it is today and an abrupt switch to drier conditions was encountered at the beginning of the Pleistocene (about two million years ago); this has become progressively more marked during the ensuing interval of time. Evidence for climatic change is supported by changes that are seen in the composition of the fossil faunas and in the anatomy of individual fossil species. The sudden appearance in Africa of zebras two million years ago may be interpreted to suggest a sudden expansion of savanna grassland and depletion of the formerly more extensive woodland. Individual species of both fossil elephants and fossil pigs show a progressive increase in the size and height of their teeth during the late Pliocene and early Pleistocene; this suggests adaptation for processing a larger percentage of grass in their diet and in turn supports the idea of expansion of drier grassland conditions. Similar conclusions may be drawn from the study of oxygen isotope ratios in the Plio-Pleistocene sediments and by pollen spectra preserved in such sediments. Summarizing all the available evidence, it would seem that at the beginning of the Pleistocene the area to the east of Lake Turkana was both cooler and more humid than it is today. The lake was fed by large permanent and ephemeral rivers whose banks were lined with thick gallery forest, and the deltas at the mouths of these rivers were clothed with fairly dense vegetation. Away from the rivers and lake shore the dense vegetation gave place to wooded savannaland. The extent of the tree cover fluctuated continually during the Pleistocene but there was an overall increase in aridity which resulted in the semidesert conditions seen there today.

The sequential changes seen in the anatomy of the fossil animals reflect changing environmental conditions but may also be used for dating purposes. The gradual increase in size of fossil pig and elephant teeth has proved particularly useful in this respect, providing a means of correlating the various hominid-bearing sites of eastern and southern Africa and providing age estimates for those sites for which radiometric dates are unavailable.

Thus, by studying the fossil mammals associated with the remains of early man, observing the changes that took place in the faunas of the past, and interpreting such changes in the light of the behavior and ecological adaptations of their living representatives and counterparts, we are able to make an assessment of the different environments in which our forebears lived and evolved. We also are able to assess the relative geologic age of individual specimens of fossil man on the basis of animals associated with them, and to begin to understand the stimuli that may have affected the course of human evolution.

So far, only a few hominid specimens have been recovered from the late Pliocene portion of the Koobi Fora sequence (2½–3½ million years). These all appear to represent specimens of *Australopithecus afarensis*, better known from many specimens recovered by the joint French-American project at Hadar in Ethiopia and by footprints discovered by Mary Leakey's team at Laetoli in Tanzania. The early Pleistocene sequence at Koobi Fora (1.3–2 million years) has proved far more productive in this respect. From this younger portion of the sequence have been retrieved many specimens of *Australopithecus boisei*, the East African robust australopithecine that represents a distinct sidebranch from the main course of human evolution. *A. boisei*, whose large molars and small incisors have been interpreted to indicate a primarily vegetarian diet, was strongly sexually dimorphic. Both sexes had relatively small brains (about 500 cc) but males stood between four and four-and-

a-half feet tall and had strong sagittal crests on the roof of the skull while females stood about a foot shorter and lacked the sagittal crest. Skulls of both male and female *A. boisei*, together with jaws and limb bone fragments, have been retrieved from east of Lake Turkana.

Associated with the remains of *Australopithecus boisei* in sediments of between 1.8–2 million years are the remains of *Homo habilis*. As may be seen from the "1470" cranium of *H. habilis* from Koobi Fora, the facial architecture of this species has strong australopithecine affinities but the brain was much larger (about 750 cc) and most authorities believe that it was *Homo habilis*, rather than the australopithecines, that manufactured the first recognizable stone tools.

Sediments of the same age at Koobi Fora have yielded a somewhat differently shaped cranium, cataloged in the National Museum of Kenya's collections as KNM-ER 1813. Like other specimens of *Homo habilis*, and in contrast to the robust australopithecines, the "1813" skull has large incisors and small molar teeth which indicate a generalized and omnivorous diet. The brain is, however, of comparable size to that of the robust australopithecines. Authorities are divided in their interpretation of this and similar specimens. Some say these represent female specimens of *Homo habilis* (despite the difference in apparent brain size between the "1813" and "1470" specimens). Others prefer to view them as gracile australopithecines similar to *Australopithecus africanus* from the cave breccias of Makapansgat and Sterkfontein in South Africa, and which may represent the stock from which *H. habilis* evolved.

In the younger part of the Early Pleistocene sequence at Koobi Fora (1.3–1.6 million years) the robust australopithecines persist but here they are accompanied by a more progressive form of the *Homo* lineage and which appears to be the earliest example of *Homo erectus*. The *H. erectus* crania have even larger brains (about 850 cc) and large brow ridges but the shape of their faces is much closer to ours than that of *H. habilis*.

Thus, the fossil hominid material from the Koobi Fora succession documents the terminal phase of robust australopithecine evolution in East Africa. It also has provided the only undoubtedly male crania of *Homo habilis*, and the ear-

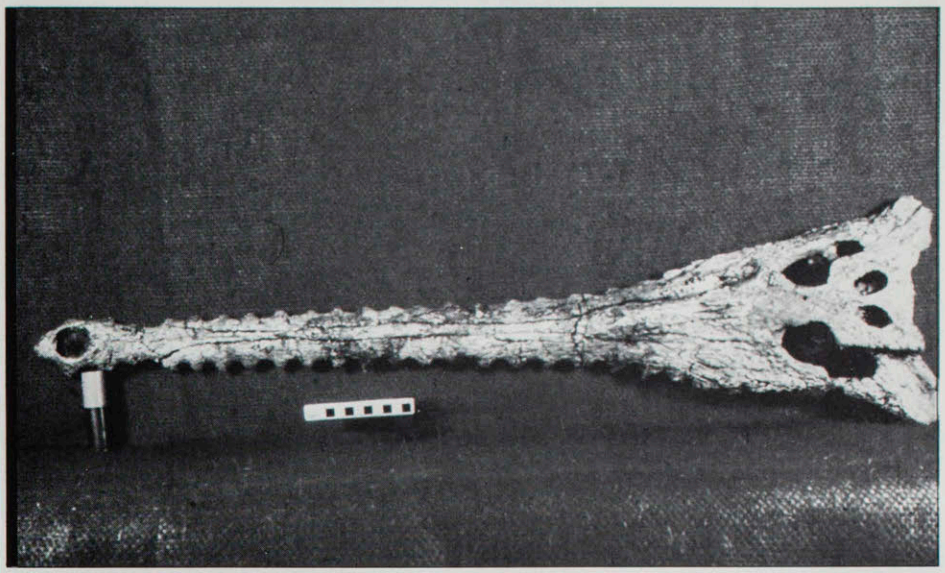
*Top: The Koobi Fora sandspit from the air. The field headquarters buildings are located at the base of the spit. In the foreground are exposed sediments of Early Pleistocene age.*

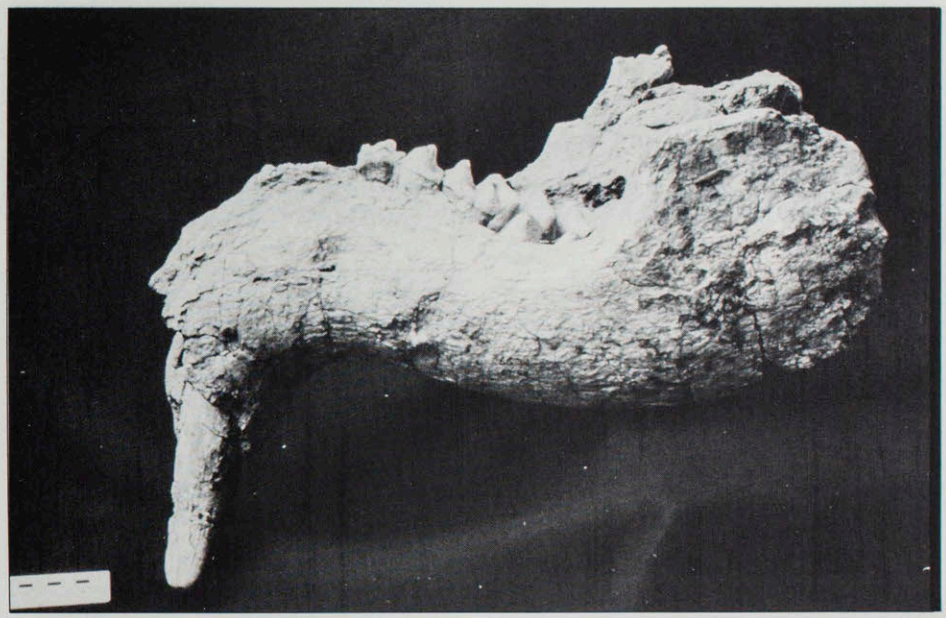
*Center: View of the late Pliocene exposures at the south end of the region investigated by the Koobi Fora Research Project.*

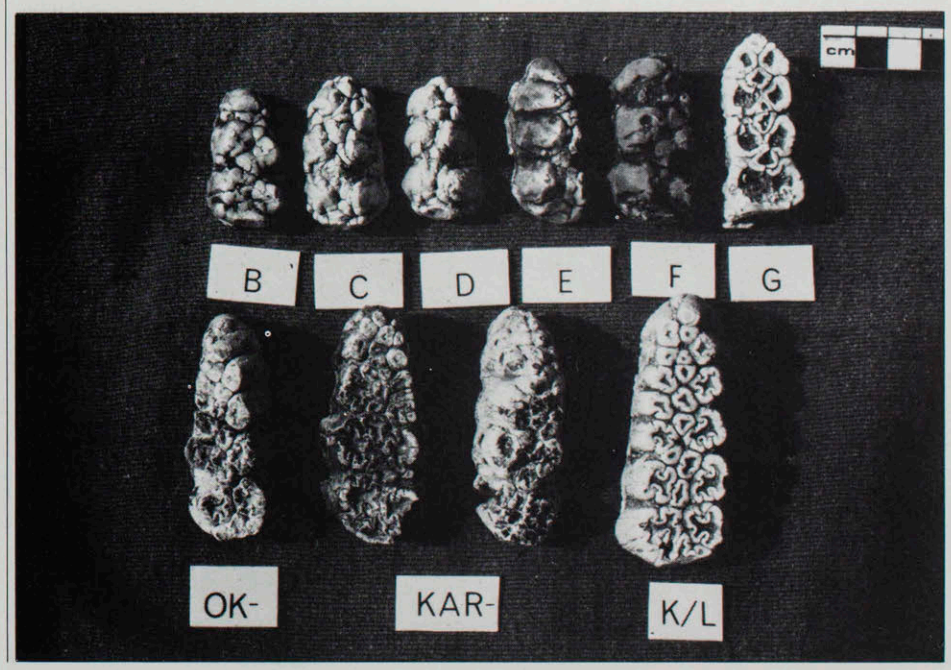
*Bottom: Digging for water in a sand river. Bernard Ngenyeo, who discovered the "1470" skull, is on the left, Kamoya Kimeu on the right.*

liest examples of *Homo erectus*, the species immediately ancestral to ours that harnessed fire and developed a very complex stone technology. It is unfortunate that, owing to the vagaries of sediment accumulation, there are gaps in the geologic record both at Koobi Fora and elsewhere that might have contributed evidence concerning the origin of *Homo habilis* on one hand and that of *Homo sapiens* on the other. Moreover, evidence is accumulating to suggest that true hominids diverged from the stock leading to the modern African apes only about five million years ago, and this time interval is also only poorly documented in the African fossil record. However it is conceivable that sediments of appropriate age to document these critical phases of human phylogeny might yet be identified in the Lake Turkana basin. Two of the earliest *Homo sapiens* crania yet recovered (dated at about 100,000 b.p.) were collected just north of Lake Turkana by a National Museums of Kenya expedition in 1967 while a humerus and jaw of uncertain hominid affinity, and dated at approximately four and five million years respectively, were recovered from the sites of Kanapoi and Lothagam to the southwest of Lake Turkana by Harvard University expeditions in the late 1960's. During the next few years the Koobi Fora Research Project will be expanding its field programs to seek appropriately aged fossiliferous horizons within the Lake Turkana basin in the hopes of resolving some of the still outstanding problems in human evolution.

Meanwhile, the potential ramifications of existing field programs will still take some time to explore satisfactorily. The geology and stratigraphy is continually being refined to provide additional insight into the past history of the region. For example, we had assumed since the onset of our investigation that Lake Turkana, the second largest lake in Kenya, had existed throughout the sequence we were investigating. Recent








*Top: One of the common crocodile fossils throughout the sequence is the slender-snouted fish-eating* Euthecodon brumpti *whose skulls grew to four feet in length. Also present was a broad-snouted crocodile, some individuals of which attained lengths of 30 feet or more. Neither are closely related to the Nile crocodile which occurs in Lake Turkana today.*

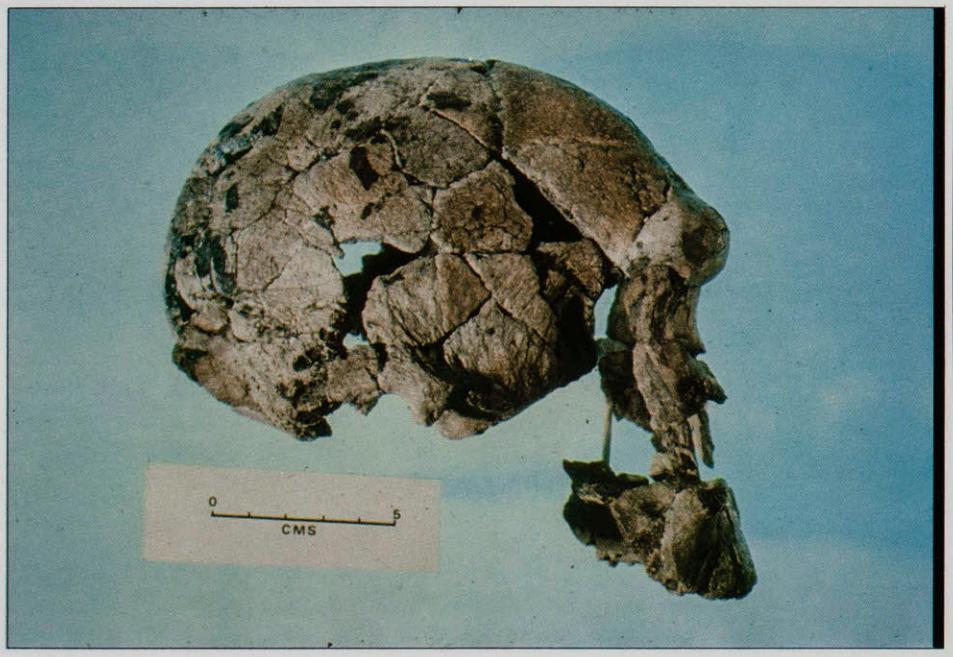
*Center: Mandible of* Deinotherium bozasi *which was distantly related to the elephants but which had tusks only in the lower jaw.*

*Bottom: The teeth of* Kolpochoerus limnetes *gradually increased in size and height through time. One may obtain an approximate idea of the age of the sediments by measuring the size of the preserved* Kolpochoerus *teeth. Teeth in the bottom row are from the Koobi Fora region, those in the top row are from slightly older Pliocene sediments at the Shungura locality of the lower Omo River in Ethiopia.*

*Above: Fossil kudus were common in the Early Pleistocene portion of the Koobi Fora sequence. These specimens were ancestral to, but slightly smaller than, the living greater kudu.*

*Above: Zebras (genus* Equus*) are not found in Africa earlier than 2 million years ago. Their migration from Eurasia is thought to have coincided with the spread of savanna grassland in Africa. This skull represents a new fossil species which was also the largest zebra ever known.*

*Below: Male specimens of* Homo habilis, *as represented here by KNM-ER 1470, have much larger brains than the australopithecines and lack the sagittal crest on the top of the skull. This and similar specimens from Koobi Fora have been retrieved from levels below the KBS Tuff, which is now dated at 1.89 million years.*




evidence has come to light to suggest that for much of the Pliocene the lake was only an intermittent feature and for the rest of the time the area was drained by an immense river that flowed into the Indian Ocean. The effect that this new scenario might have on former interpretations on the past distribution and behavior of the fossil faunas is still being explored.

The archaeological investigations are also addressing new questions. Many sites have been excavated and comparisons have been made between the Oldowan stone tradition as represented east of Lake Turkana and that at other sites such as Olduvai Gorge. Experiments are now being undertaken to determine how the artifacts were made and what they could be used for. Others are in progress to determine how undisturbed the archaeological sites are and whether the accumulation of large numbers of stone tools is due solely to human agency or is modified by processes of geological sedimentation. Studies are being made to reconstruct the precise landscape at which the sites occur and to infer whether or not the spatial distribution of the sites might reflect the preferred behavioral patterns of our ancestors.

Now that most of the fossil vertebrate material has been identified and described, more attention may be given to questions arising from such initial investigations. Why, for example, were there so many more species of mammals in this region during Pliocene and Pleistocene times than in any comparably-sized area of Africa today (four species of hippo, three species of giraffe, three of elephants, at least two of hominids, etc.)? Why was the Indian elephant much more common than the African in Africa during the Plio-Pleistocene? What was the functional significance of gigantic size in pigs and how did this affect their behaviour? How accurately do the species preserved as fossils represent all the animals actually living in the region in the past?

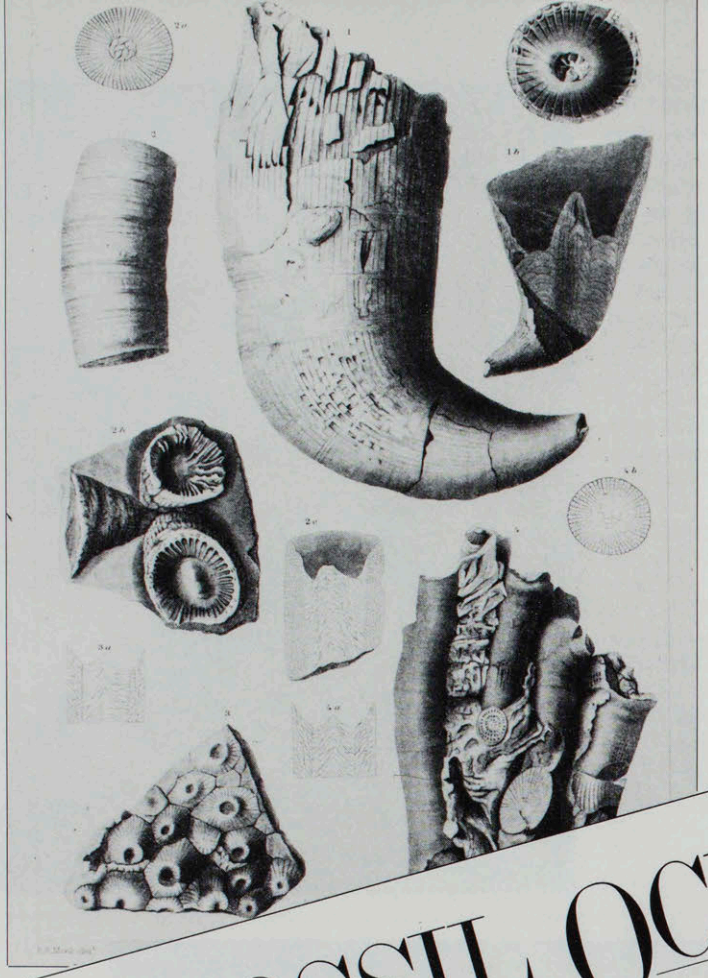
To address and resolve all the questions posed by the fossil and archaeological material recovered from east of Lake Turkana clearly will take considerable further work. However, in conjunction with similar investigations being undertaken in other parts of eastern and southern Africa, there is every hope that the next decade will see additional great strides in our understanding of man's origin and evolution. For the moment it would appear that Darwin was correct in referring to Africa as the cradle of civilization. It remains for us to determine why this was so, and what prompted the acquisition of the large brain and upright stance that distinguish us from other members of the Animal Kingdom.

*Dr. John M. Harris is Chief Curator of the Division of Earth Sciences and Consultant Paleontologist to the Koobi Fora Research Project. Before joining the staff of the Natural History Museum in 1980 he was Director of Paleontology at the National Museums of Kenya for 8½ years. Casts of the hominid specimens mentioned in this article, and others from Koobi Fora, Olduvai and Laetoli, will shortly be seen in a new Early Man exhibit in the Hall of Evolving Life.*

*Top: KNM-ER 1813, discovered by Kamoya Kimeu, is of similar age to the "1470" skull but its relationship is still being debated. Some authorities refer to it as a female* Homo habilis, *others have suggested that it is a gracile australopithecine. Its teeth are similar to those of* Homo habilis *but the brain size is smaller than that of KNM-ER 1470.*

*This skull, discovered by Bernard Ngenyeo who also discovered the "1470" skull, is between 1.5 and 1.8 million years old and represents one of the earliest known examples of* Homo erectus. *It has the heavy brow ridges typical of* H. erectus *and a larger brain than* Homo habilis.

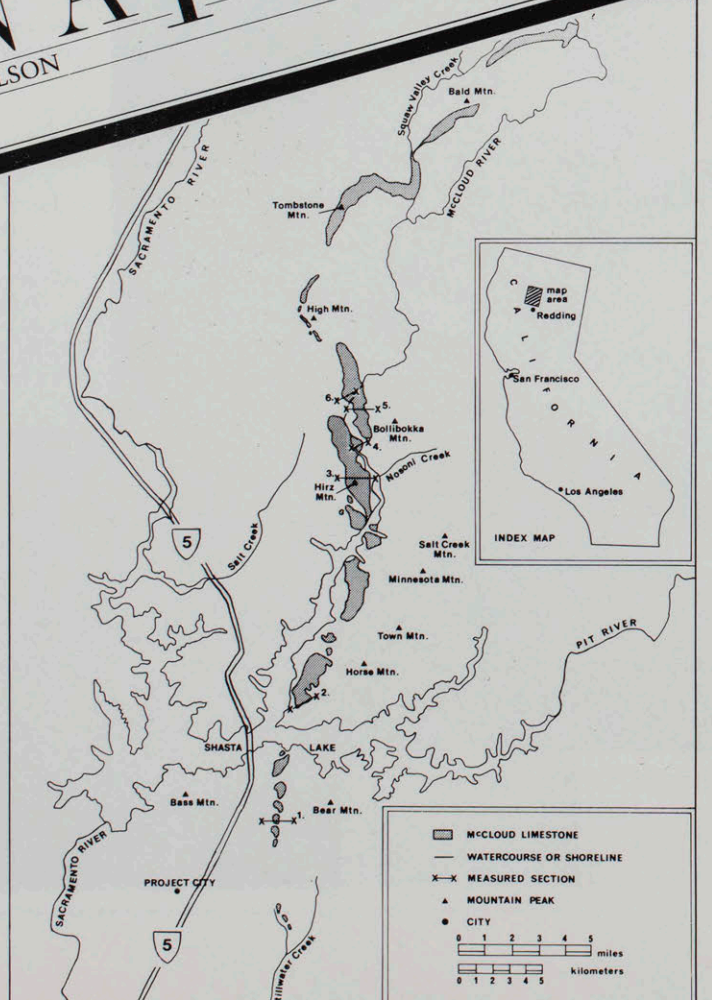
*Inset: These hominid and hippo footprints were discovered in the Koobi Fora Tuff (about 1.5 million years) during a paleoecological excavation made by Dr. Kay Behrensmeyer. The three hominid tracks (from bottom right to top left ) are about the size of a lady's size 7 shoe. It is not known whether these represent* Homo erectus *or* Australopithecus boisei.



*Fielding B. Meek's plate published in 1864 showing corals from the McCloud Limestone. The large horn coral (top row, center) is two inches across at its broad end. Other specimens are to same scale.*

# LIFE IN A FOSSIL OCEAN

by EDWARD C. WILSON




*Map showing parts of Shasta County where the Permian age McCloud Limestone (patterned area) is exposed.*

In 1962, having co-authored a study of 280 million year old corals from eastern Nevada with Ralph L. Langenheim, Jr., a paleontologist at the University of California, Berkeley, I was looking for a new project to tackle. He suggested that I work up the coral fauna from a rock formation of similar age in northern California known as the McCloud Limestone from which he and his student, V. A. McCutcheon, had described a new coral. Twenty years later, I still continue that study (among others), but enough information has been published to warrant a synthesized popular account of this little known wonder: the remains of an ancient, equatorial, coral sea in the snowy mountains of Shasta County.

First, some background:

On March 26, 1853, almost exactly 129 years ago, the California State Senate asked John B. Trask, a handsome medical doctor who was a member of our sister institution, the California Academy of Sciences in San Francisco, and who did some "geologizing," to divulge his knowledge of California geology. Trask submitted several reports over the next few years, including brief descriptions of his explorations in the Klamath Mountains, where he said he worked mostly on foot with his "attention well occupied rather in preservation of his life against the dangers of the wilderness and its denizens, than in searching for geological formations." There, in 1855, he discovered the limestone that later would be named after the nearby McCloud River, considering it to be of Carboniferous age and a potential source of coal, since the rich coal formations of the eastern and midwestern United States and Europe were of similar age. The delighted senators, already heavily into gold and silver, wanted that coal.

But there wasn't any coal. The senators were displeased.

Several eastern, southern, and midwestern states had hired professional geologists with profitable results, so on April 21, 1860, the California State Senate appointed Josiah D. Whitney, a highly respected geologist from Massachusetts who had worked successfully on various state geological surveys, as head of the newly created Geological Survey of California. Give us, the senators charged, "an accurate and complete Geological Survey of the State... with a full and scientific description of its rocks, fossils, soils, and minerals, and of its botanical and zoological productions."

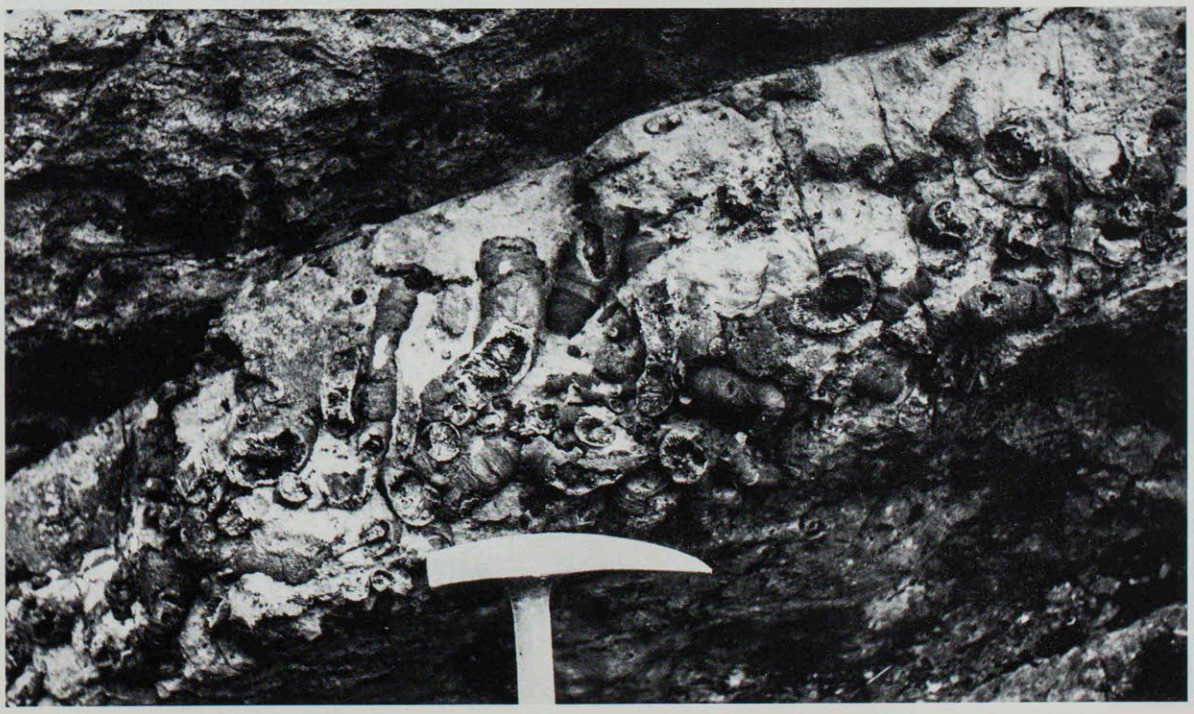
Whitney formed a staff with topnotch young scientists and accepted a few gifted volunteers. His number one man, William H. Brewer, a chemist-turned-botanist who had been teaching in Pennsylvania, wrote entertainingly to his brother about his experiences and the letters later were published *(Up and Down California in 1860–1864*, available in the Museum bookstore). From these, we learn that the Survey field party camped on Friday, September 19, 1862, at the ranch of John S. P. Bass, a site now in the village of Mountain Gate, just north of Redding, and spent the weekend collecting fossils from "some interesting limestone ridges nearby" belonging to the formation discovered by Trask. The fossils were sent to Fielding B. Meek, a paleontologist at the Smithsonian Institution in Washington, who published the results of his study of them in 1864 in the first book on paleontology by the Survey. He described and illustrated twelve fossils from the McCloud Limestone: four corals, a large marine snail, and seven other kinds of shelled invertebrate fossils known as fusulinids and brachiopods.

Information about the ancient sea's fauna had begun to appear.

But the business-minded senators, having gold—not fossil—fever, were unhappy again. Indeed, an appropriation for the year 1869 was refused Whitney (funds then were disbursed *after* expenses had been incurred, if they could be justified), and he shortly left California for a professorship at Harvard University. The Survey disbanded.

Study of the McCloud Limestone languished through the early twentieth century because of its slight economic importance and relative inaccessibility, although a few reports chiefly of academic interest touched on it. Then, in 1932, Norman E. A. Hinds, a geologist at the University of California at Berkeley, stimulated further work by reporting that geology student Harry E. Wheeler of Stanford University had discovered that small fossils called fusulinids in the McCloud Limestone were not like those found in rocks of the Carboniferous Period, but were the kinds from the next younger period, the Permian, making the formation the same age as the oil-rich rocks of Texas.

Detailed information about the fusulinid fossils was then presented by paleontologists Wheeler and M. L. Thompson of the University of Illinois, and, in 1965, by John W. Skinner and Garner L. Wilde of Humble Oil and Refining Company of Midland, Texas. Skinner and Wilde, in a near monumental work, recognized 167 species of fusulinids in the formation and reported that its aggregate thickness (previously thought to be a modest 1,000 to 2,000 feet) was actually



*Layer in the McCloud Limestone having abundant, large horn corals. Geology hammer is seven inches across.*

more than 7,000 feet. The information obtained about the distribution of the fusulinids in this thickness has become useful in oil and mineral exploration, as Humble Oil had anticipated.

A few additional fossils from the formation were reported in the 1960's and 1970's by paleontologist Rodney Watkins (brachiopods) of Redding and myself (mollusks).

The formation crops out in a narrow, broken band from a few miles south of Shasta Lake northwards for about thirty miles through rugged, forested mountains to the southern shores of Lake McCloud near the town of McCloud (see map). Its layer cake-like beds were horizontal and continuous while they formed on the sea floor, but later pulses of mountain building broke and tilted them steeply eastwards so that mostly cross sections are exposed now. The outcrop band is made up of disconnected blocks, somewhat reminiscent of a thirty-mile-long derailed train. To collect fossils from the formation scientifically, it is necessary to measure (yes, we are measuring mountains with a tape measure) up the west side of the blocks, collecting fossils and keeping records of their positions in the thickness. Naturally, the layers that are lower were formed before the layers that are higher and therefore any fossils in lower beds are older than ones in layers above. Careful collecting will show any changes that occurred in the faunas.

Geologists long had thought that the formation was like similar appearing formations elsewhere, that is, a section measured across it in one place would be equivalent in age to a section measured across it anywhere else. In their 1965 study, Skinner and Wilde showed that the formation is more complex than that. No one block in the outcrop band represents more than a part of the original thickness. Therefore, it is necessary to measure and collect multiple sections in order to sample the entire 7,000 foot thickness represented.

With the help of several dedicated field assistants, I measured six sections across the formation at critical places and collected the corals and other fossils. The results of this study were published by the Museum earlier this year so that now there are two groups of animals from the formation that are rather well known: fusulinids (167 species) and corals (49 species). When information obtained from these is combined with that known of other organisms and of the physical composition of the rocks in which they are found, a picture emerges of the ancient sea.

The McCloud Limestone formed in very earliest Permian times, beginning about 290 million years ago. World geography at that time was different than it is now. There was one supercontinent, ancestor of all the present continents, with future North America at its western edge. The equator crossed it from the areas of present day San Francisco to Newfoundland. Calvin H. Stevens, a paleontologist at California State University at San Jose, has suggested that the sea and land configurations of the far western United States may have looked something like present Southeast Asia. An east to west section would have shown land east of Utah, a marginal sea comparable to the South China sea covering much of western Utah and eastern Nevada, a peninsula or islands running north to south down central Nevada like the Malay Peninsula and Borneo, a parallel sea to the west in western Nevada and northern California, bordered on its western edge by a series of volcanic islands like Sumatra and Java, with a very deep oceanic trench west of these like the Sunda Trench.

The McCloud Limestone was formed in the western part of this area, I suspect near the outermost islands. Other workers think that it may have been laid down a much greater distance to the west, perhaps more than 3500 miles, and later was moved to its present position by continental drift forces.

Ferruh Demirmen and John W. Harbaugh, Stanford University geologists, carefully studied the rocks of the formation and concluded that they originated as sediments in shallow water because of the presence of abraded and fragmented fossils and submarine plants that could live only where sunlight reached them. They speculated that land was nearby on the southeast and that open ocean lay to the northwest.

Nearby volcanoes had been erupting in the area for many millions of years, as shown by the great thickness of volcanic sediments underlying the McCloud Limestone, but they either ceased eruption while it formed or else it was somehow protected from accumulating any volcanic sediment.

The water was shallow, clear, and sunny, the bottom sandy, the climate tropical, with islands. What about the life?

We know nothing definite yet of the land life in this area during Permian time because fossil land plants or land animals have not been found here. Judging from comparable areas, however, the islands may have had ferns and perhaps pine-like trees, but no flowers, no coconuts. There may have been insects and lizard-like reptiles, but no birds, no people. Still, the sky would have been blue, the winds

*North end of the McCloud River Arm of Shasta Lake showing lightly wooded cliffs of the McCloud Limestone (right foreground and middleground) extending to notch in High Mountain (left skyline). Mt. Shasta in distance*

warm, and there was rain and probably streams, waterfalls, and other amenities we associate with equatorial climes such as grand sunsets and views of distant islands. Certainly there were interesting seashells and lovely white corals cast up by the waves on the broad sandy beaches.

We are more certain of life in the sea. Blue-green algae lived in the shallowest water, moved about by the tidal currents. Snails of numerous kinds thrived, the largest of which were several inches across and shaped like modern top shells. Clams of several kinds lived in the sand and mud. A strange, extinct, clam-shaped mollusk with no common name except rostroconch was abundant in places. We would love to know where and how it lived. Chambered nautilus-like creatures swam and floated about and perhaps crawled on the bottom. In the white, sandy stretches, colorful corals with shapes like modern brain corals, stag horn corals, and organ pipe corals grew scattered about but did not form coral reefs, although some colonies were several feet across. In patches of black mud, very long horn corals (some as much as two feet) lay around in log-jam abundance. Sponges were attached to rocks. Bryozoans grew on shells in lacy splendor. Here and there, long-stemmed sea lilies an inch or two across at the "heads" were attached and large spiney sea urchins crept about. There were fish that left their remains as tiny, cone-shaped teeth and perhaps an occasional one of the big sharks named *Helicoprion* because their teeth were in a single row, tightly spiraled. Teeth of this shark have been found in nearby rocks of similar age. But there were things missing that we see in modern equatorial seas: no turtles, no porpoises, no sea snakes. No Club Med.

And then came change. Earthquakes shook the area, new islands rose from the sea and shed rocks from their cliffs and streams into the sea, which rounded them into pebbles, cobbles, and boulders in such numbers that they gradually covered the sandy sea floor. Finally, lava flows, ash falls, and mud slides buried the old sediments to a depth of thousands of feet.

It wasn't until fifty million years later, in the Triassic Period, that the volcanoes quieted enough so that some of the former splendor returned. By then, however, life had changed and giant reptiles swam in the sea and dinosaurs prowled the beaches. But this too passed and the area became such an integral part of the growing North American continent that true oceanic conditions never returned to it.

These stories lie in the rocks of the mountains, available to anyone who learns to read them. Geologists and paleontologists have that ability, but anyone can try and perhaps succeed. A good place to see the McCloud Limestone is from Interstate Highway 5 near the southern end of Shasta Lake. South of the lake, it forms the Gray Rocks east of the highway being quarried by the Calaveras Cement Company. Northward, views of the lake from the highway include the steep gray hills and cliffs of the formation on the east shore. From Bailey Cove, frequent tours leave by boat to the North Gray Rocks, famous for the Shasta Caverns here in the formation. Near the cave entrance, poorly preserved fossil corals form star-shaped patterns in the limestone.

Gilman Road leads east from Highway 5 at Salt Creek and skirts the slopes of Hirz Mountain to the McCloud River Arm of Shasta Lake, where fossil corals, parts of sea urchins, and other fossils may be seen in the rocks on both sides of the river just north of the bridge. Here, the hardy may wish to climb the rugged great cliff east of the bridge and be rewarded by observing scraps of corals, snails, and other fossils in the rocks.

Farther north, one can drive from the town of McCloud southeast to Lake McCloud and perhaps see fusulinids and corals in the north end of the formation where it crops out near the boat ramp on the Battle Creek Arm of the lake. In the same area, deer hunters spending a night on Bald Mountain may see parts of crinoids in the bare gray rocks of the formation.

True woodsmen might hike the eleven miles from Girard Road to Tombstone Mountain, the peak of which is formed by the youngest part of the formation. Here there are fossil corals, snails, and brachiopods and here the great Sasquatch has been sighted snuffling and chortling through the woods.

It is to Tombstone Mountain that we soon will return to complete the study of the McCloud Limestone corals. It is here that Philip Owen, my unflagging field assistant, will find the answer to his burning question: Will the Sasquatch help tote rocks the blankety-blank eleven miles to the road?

*Edward Wilson, the Museum's Curator of Invertebrate Fossils, wishes to dedicate this article to the people of Shasta County (home of the McCloud Limestone), whom he found to be so positively attuned to the extraordinary natural beauty surrounding them that they viewed even drought years with low reservoirs as "more beach than ever before."*

*Closer view of cliff shown in Figure 3. For scale, note car below on Gilman Road at east end of the McCloud River Bridge.*

# CURSE OF THE FOSSIL MARLIN

by HARRY L. FIERSTINE

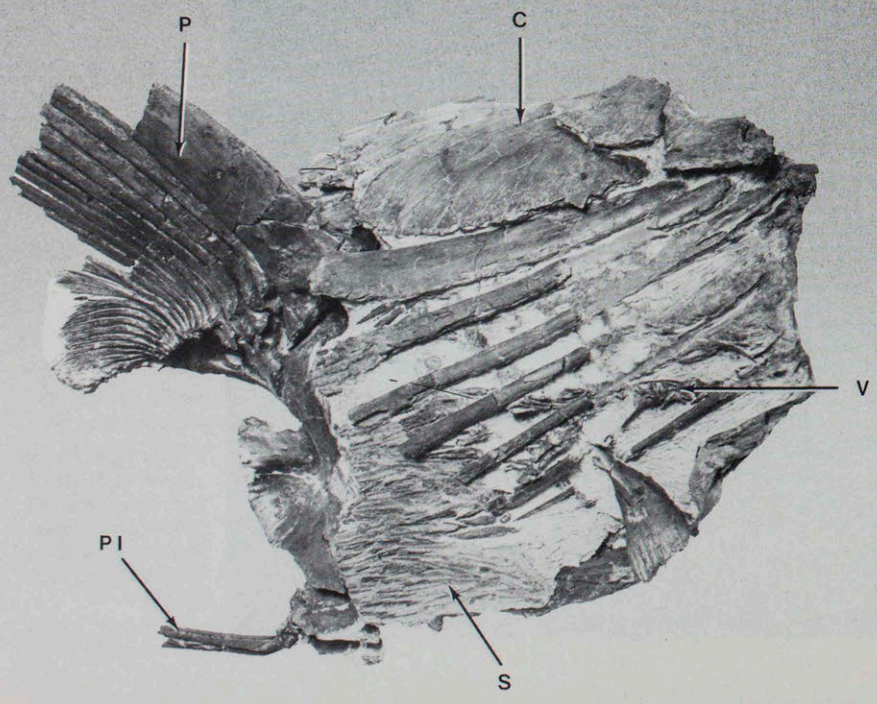
A field expedition rarely meets its goals without being confronted with unforeseen obstacles that must be overcome. Judicial planning will take care of most potential problems, such as equipment, governmental permits, supplies, transportation and weather. However, the most unpredictable hurdles are often associated with interpersonal relations, particularly cultural differences and miscommunication. Proper solutions must be found that regard local customs and preserve self-respect without sacrificing the mission of the expedition. Museum exploration has progressed beyond the rape-and-pillage philosophy exhibited by the dashing Indiana Jones in the recent box-office smash, "Raiders of the Lost Ark." In 1980, as a Research Associate in the Vertebrate Paleontology section of the Museum, I was involved in a fossil collecting expedition to the Philippines that at times seemed periled by unplanned forces. I want to share some of these experiences with you.

A Philippine marine biologist wrote, asking me if I would be interested in obtaining a fossil that had been discovered on a friend's farm 260 kilometers north of Manila. At first he had written paleontologists at the Natural History Museum in Paris, and they referred him to me. The letter contained photos that definitely indicated the material belonged to a billfish.

This discovery was exciting, because the fish was probably a marlin of the genus *Makaira* (huge size and round bill), and the completeness of the specimen would probably allow a direct comparison with features of the two living large marlins, *Makaira indica* (black marlin) and *Makaira nigricans* (blue marlin). This was the first fossil billfish discovered in Asia and the first fossil fish of any kind (except for a shark's tooth) ever discovered in the Philippines.

I began to correspond directly with the landowner, Antonio Araneta, Jr. He gave me permission to collect the specimen and offered me assistance in putting together the expedition. The field party could receive board and room at the farm and any necessary supplies, transportation, tools or labor would be provided at a reasonable fee.

One couldn't ask for more cooperation and hospitality. Armed with this in-




*Cheek, shoulder, and throat regions of fossil marlin excavated by our expedition and prepared by Mary Odano, Natural History Museum of Los Angeles County. The front is toward the right and the overall length of this piece is approximately 60 centimeters (2 feet). Letters indicate cheek region (C), pectoral fin (P), pelvic fin (P1), throat scales (s), and vertebrae (V) of presumed swallowed prey. (Photography by Cal Poly Audiovisual staff, San Luis Obispo.)*

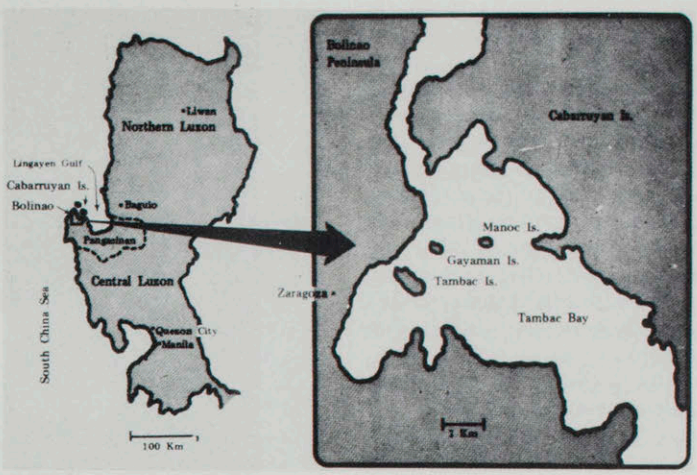
formation, I applied for and was awarded a National Geographic Society grant (along with Dr. Bruce Welton, formerly Associate Curator of Vertebrate Paleontology, Natural History Museum of Los Angeles County). The grant specified that we spend one month collecting the fossil marlin and doing a geological and paleontological reconnaissance of the surrounding countryside.

Contrary to Murphy's Law, everything came together, even though any delay of departure after June 1 would postpone the expedition one full year. All of our Filipino correspondents stated that the condition of the roads and ability to work outside would be severely hampered after July 1, which is one month into the rainy season. The National Museum of the Philippines granted us permission to remove fossils to the United States for study, passports and visas were in order, equipment was purchased, and Antonio Araneta, Jr., was going to meet us at the Manila airport. Bruce and I were accompanied by my fourteen-year-old son, Kory, who was going to be our "go for" and who was traveling as my guest. I suppose our small field party constituted a mini-expedition; anything greater would be boastful.

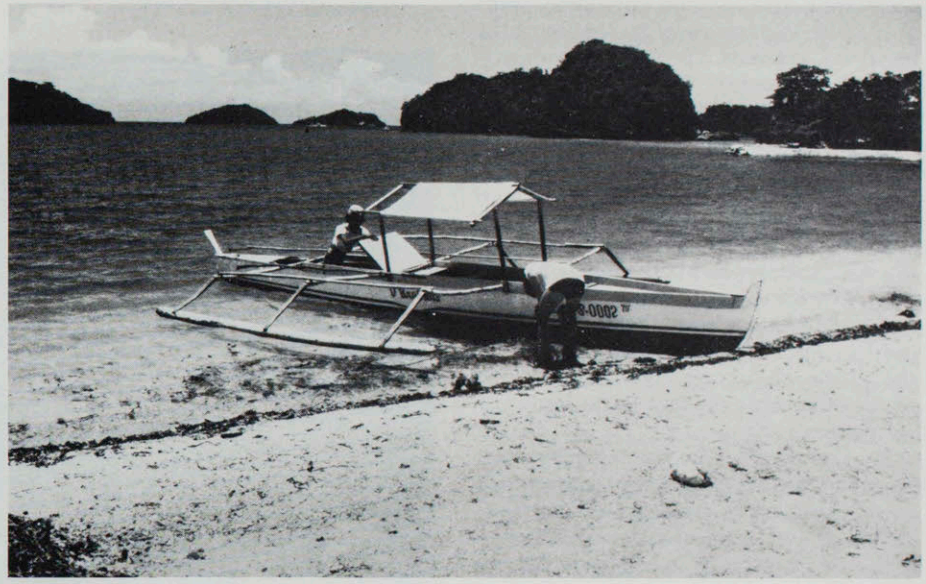
When we arrived in Manila, we were met by our host, a smiling, fortyish, handsome and olive-skinned man who was dressed in slacks and polo shirt and holding a clutch bag. His driver loaded our luggage into a Toyota sedan and drove us to our hotel, giving us our first memorable experience in Manila traffic.

We planned a couple of days in Manila in order to purchase supplies, to pay our respects to the Director of the National Museum (who must issue the export permit for the fossils) and to chat with some Filipino earth scientists about the area we hoped to explore. With Tony's (Antonio Araneta, Jr.) help we accomplished all of these things. He lent us his car and driver and arranged for one of his employees, Wilfredo Guzon, to act as our guide. To our surprise, we experienced a minimum of red tape, even from civil servants. Once they understood our request or problem, we received an answer or a solution. Since English is taught as a compulsory second language in all Filipino grade schools, we did not have an actual language barrier. However, since their national language, Pilipino, is their first language, English is commonly spoken with such a heavy accent that understanding it is difficult to the untrained ear. We often had to ask people to repeat their statements.

By now it began to dawn on us that Tony was not a typical farmer. We eventually learned that he is a member of an old Philippine family. He holds a bachelor's degree from University of Notre Dame (South Bend, Indiana) and a Ph.D. from Oxford University (England). His doctoral dissertation was on the his-




*Above: Site for 1980 National Geographic Society expedition to Tambac Island, Northwest Central Luzon, Pangasinan Province, Philippines (map prepared by Cal Poly Audio-visual staff, San Luis Obispo).*



*Above: Native banka (motorized outrigger) with Hundred Islands, a tourist attraction located about 25 kilometers east of Tambac Island, in the background.*

*Below: A young goat is being prepared for a feast celebrating the final departure of the expedition from Tambac Island. Laddie, the spiritual medium who helped excavate the marlin fossil, is on the right.*

tory of the Communist Party in the Philippines. He represented the District of Manila in the Constitutional Convention in the early 1970's and was imprisoned for nine months for political reasons by President Marcos following the disbanding of the convention. Tony decided that, with the existing political climate, he had better not return to politics. When he was released from prison in 1974, Tony involved himself in Pacific Farms, Inc., with a corporate office in Manila and field operations 260 kilometers north in Pangasinan Province.

Tony met us in the coffee shop of our hotel soon after we unpacked and told us the following fantastic story. He became aware of the fossil in 1975, although it had been discovered earlier by his employees. At first only the tip of the rostrum (bill) protruded from a cliff face and workers hung their shirts on it when collecting rocks for a dike. After a rainstorm, some of the cliff eroded away and more of the fossil was exposed. The workers broke off the bill and used the pieces as sharpening stones for their bolo knives.

At this time Tony learned of the fossil's existence, came to see it, and recognized its significance as an animal remain. He eventually had a locked shed built around it to protect it from the weather and pilferers and offered five pesos (one-third of a day's pay) for the return of any parts. Several large pieces that fell from the fossil during construction of the shed, as well as the pieces that were returned for a reward, were removed to a guest house for safekeeping.

Pangasinan Province is currently a center for spiritual faith healers, particularly those involved in psychic surgery. Tony used to show the fossil to the faith healers who came each year to celebrate the end of the harvest. One of them went into a trance and described a story of the fossil's origin. He told Tony that it became buried in an explosion and that someone was riding on its back (like a boy on a dolphin). The medium thought that this rider was one of the "first men" and that he was from the lost continent of Mu (or Lemuria), the Pacific equivalent of Atlantis. If the fossil was removed, then misfortune would come to Dr. Araneta and to its collector. Things had been going well in my life, and I didn't need this prophecy.

Tony was greatly concerned with the prediction of the spiritual medium and took steps to make us sensitive to the issue. He didn't want to lose his wealth or corporation, which he interpreted as the most likely misfortune to fulfill the prophecy. He wanted assurance that we were not economic geologists who were searching for valuable minerals rather than fossils. If we were to find economically important resources, then President Marcos had authority to confiscate his lands. It didn't take long to convince him otherwise. As Tony, himself, was a member of the National Geographic Society,

*Above: Psychic surgery took place in this converted garage in Quezon City.*

*Below: Salt evaporation ponds at Pacific Farms, Inc., Tambac Island.*

*A corrugated metal shack was erected to protect the fossil marlin at Tambac Island.*

our association with that world-famous organization was credential enough.

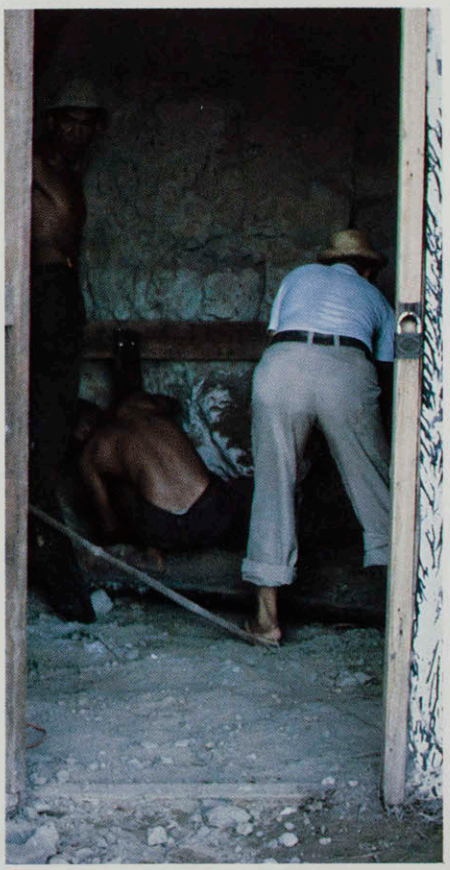
Since arriving at Pacific Farms, Tony has observed psychic healers and believes they have strong curative powers. He has become so involved in psychic phenomena that he helped found the Philippine Society for Psychical Research, an organization that tests if psychic phenomena (particularly psychic surgery) is a valid form of medicine.

During our second day in Manila, Tony had made plans for us to watch a psychic healer in action. In preparation for this visit he left with us albums of photos taken during various psychic operations and literature and unpublished reports from the Philippine Society for Pyschical Research. At this point Bruce and I couldn't understand the purpose of our visit to the faith healer other than to make us more culturally aware. It was our first evening in the Philippines, we were tired and suffering from jet lag, and here we were poring over documents and literature about psychic healing. We tended to be very skeptical and critical of the experimental approach in the reports.

The next morning we were driven to Quezon City, about one hour out of Centro Manila, where we stopped at a one-story stucco home, quite similar to those seen in the older parts of Southern California cities. We entered the garage, which had been converted into a "chapel." It was furnished with several rows of benches, a few scribbled verses tacked on the smudged walls, a stuffed boar's head, a picture of Christ and a coat rack. The raised altar contained a padded table, a self-standing privacy screen and a podium. A comfort station was next to the altar and several potted plants that needed care were scattered around the room.

Besides our party, there were only three others in the room. An Australian with a Filipino friend sat in the front row, thumbing through a photographic album of psychic operations (they looked identical to the albums Tony had shown us). An unidentified woman was sitting quietly on a stool in front of a window. After several minutes, two men came through a door that entered the altar area. One was an American from Texas and the other was a Filipino. The Filipino, Virgilio Gutierrez, Jr., was the psychic surgeon, and the Texan was his student assistant. The Australian went forward and lay down on the table, pushing his pants downward and his shirt upward, thereby exposing his abdomen. The Australian's companion took flash pictures. Tony motioned for us to step up and watch—I was less than three feet away. The healer was on the left side of the patient and rubbed the exposed abdomen below and around the navel with cotton dipped in two kinds of liquid—one could have been alcohol and the other oil.

*Men working to excavate the fossil marlin.*



After a couple of minutes, the healer concentrated his efforts on a spot to the left and below the navel. He seemed to poke it with his index finger. All of a sudden, blood appeared and the healer seemed to be feeling inside the abdomen with his index finger. A piece of "tissue" was pulled from the opening and was placed in one of the bowls. The abdomen was wiped clean. The only mark that was visible was a slight horse-shoe shaped indentation that could have been made by a fingernail. No more blood appeared. The patient arose from the table, pulled up his pants, tucked in his shirt, exchanged a few words with the healer and departed with his friend. Meanwhile, the bowls were whisked away. None of us had our wits about us sufficiently to ask what was wrong with the Australian, if he was cured, or what was in the bowl. To this day I don't know what I saw. We noticed a lack of aseptic procedures (except possibly for rubbing the abdomen with the two liquids) and, when we questioned Tony about this later, he said that infection has never occurred following psychic surgery.

After the other patient was treated without surgery, Tony introduced the healer to Bruce, Kory and me. Tony told him about the purpose of our visit to the Philippines and about the prediction concerning the fossil. Mr. Gutierrez said that we must seek another medium's opinion about whether we should chance its removal from the earth. He said that in light of its religious and spiritual value, I might develop back pain on my right side and I must ask the medium to hold the pain for me. I silently promised myself I wouldn't ask for the pain's return. The healer thought that if we found the right medium, we could remove the fossil without disturbing the spirits. The healer suggested an individual, but Tony said he had already inquired about him and that he was out of town on vacation. Tony suggested another, one of his employees named Laddie, and Gutierrez thought he was a reasonable second choice.

As you would expect, we Americans didn't lack a topic of conversation. I

thought it a little unfair that I was the one to get the back pain. Bruce is much younger, an equal partner in this venture, and he wasn't receiving his share of the predicted misfortune. Truthfully, because of our own cultural biases, Bruce and I were skeptical of what we were experiencing, but we felt compelled to go along with the local spiritual beliefs. Kory told me much later that he was annoyed with our skepticism and our minds should have been more open. Tony did seem genuinely committed to our objective of removing the fossil. He thought that as long as the fossil was eventually returned to the Philippines (which are the terms of the permit with the Philippine government), then the spirits would allow a temporary removal. There was only one flaw in our plan: what will we do if the next medium will not allow the fossil's removal? Bruce and I decided upon a wait-and-see action.

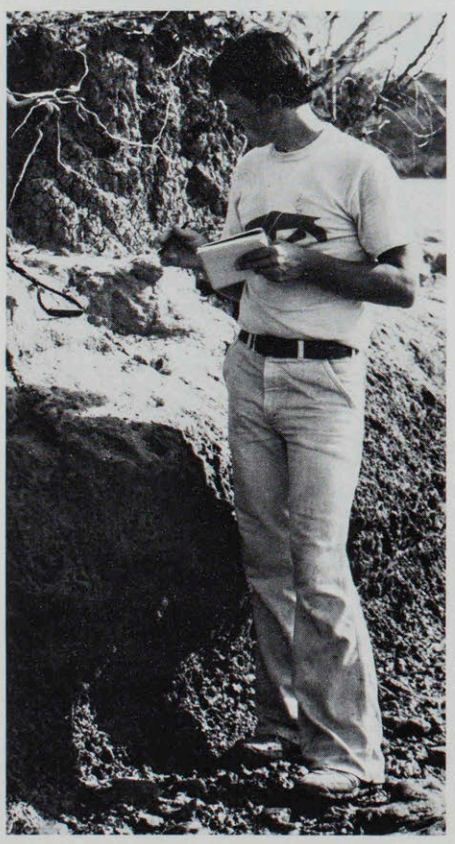
The following day Tony's driver drove us to our northward destination. We were awe-struck. Although Bruce had traveled a couple of times to Asia, Kory and I were not as worldly. I saw my first carabao, ricefields and thatched huts. We traveled to Lucap, some twenty-two kilometers from Tambac Island and then motored by a native banka (motorized skiff with outriggers) to Tambac Island and Pacific Farms. Tony didn't come with us at this time; he would arrive later.

Much to our surprise, the farm harvested marine products, not terrestrial ones. Pacific Farms, Inc., is primarily a salt operation. It consists of Tambac Island (eighteen hectares), large expanses of adjacent mudflats and aquaculture ponds, a wide, one-kilometer-long dike that connects the island with the main island of Luzon and a small amount of adjacent acreage on Luzon. Tambac Island contains the industrial operations and only three or four families live there. A large guest house where we stayed and several company houses are located on Luzon. Most of the workers live outside the corporate property. Besides the production of sea salt through solar evaporation, Tony has experimented with raising ducks, oysters, milkfish, shrimp, brine shrimp, seaweed and now guard dogs. Pacific Farms employs up to 500 workers during the salt harvest and is the main employer for the local barrio of Zaragoza and Western Pangasinan.

For the next four days we geologized and prospected the shorelines of Tambac and nearby islands for fossils. Our main mode of transportation was by boat, usually the native banka. On all trips away from Tambac, Tony saw that we were accompanied by one to three workmen who acted as boat handlers, guides, translators, and, we suspect, as bodyguards. We collected many invertebrates and fish otoliths (earbones) for the Museum and began to prepare for the removal of the marlin. We glued some loose

*Dr. Antonio Araneta, Jr., owner of Pacific Farms, Inc. and host of expedition, arriving at marlin site with his pet German Shepherd guard dog.*

*Dr. Bruce Welton, expedition co-investigator, is taking field note at fossil outcrop.*



bones together and put a plaster jacket on the exposed bone to protect the marlin from the overburden that would fall during digging. We didn't dare dig very much until the medium appeared. This caused us great concern because each day brought more and more rain and, if we didn't excavate soon, we'd be working in mud. We noticed that during occasional showers water flowed inside the shed, down the cliff face and over the fossil. It didn't take much imagination to realize that soon we would be working under a waterfall. After dinner on the fourth day, Laddie came with the president of the local espiritists' group, spread out a small brocade cloth and proceeded to go into a trance.

Everything took place in the local Bolinaoan dialect. According to Tony, who translated, Laddie said if Dr. Araneta (most of his employees called him Dr. Araneta or, affectionately, as TonyPet) would shed some blood on the fossil and if he, Laddie, would say a prayer over it every day, then it would be all right to remove it. In this way no one would meet misfortune. I must confess I was relieved and slept much better after that. As in the case of traditional medicine, if you don't like the diagnosis and prognosis of the first opinion, seek others until you're satisfied. I was content to stop at two.

I'm not sure what Tony told Laddie prior to the trance. Earlier he had been asking Bruce and me if we thought the fossil could come back to Tambac Island, rather than to the National Museum in Manila. He saw two advantages to this action. First, the fossil would come home to its burial site and might better appease the spirits and, secondly, a beautifully mounted fossil marlin over ten million years old (we have since learned the rocks are approximately two million years old) might become a tourist attraction from which the farm could profit. Bruce and I were caught in an ethical dilemma. Naturally, we wanted to appease the spirits so that we could excavate and we didn't want to disappoint our gracious host, but on the other hand we didn't want to lie. Based upon what we had already seen, we realized the fossil was probably not of display quality, although it had great scientific value. Bruce and I attempted to soft-sell the idea, agreeing that Tony's suggestion was possible. We explained we had no authority to have the fossil sent to Tambac, but would support his proposal in any way we could. We thought with extensive paleontological reconstruction (which would be expensive and time-consuming), the fossil might make an excellent display.

I learned my lesson long ago about being extremely tactful with the owner of a fossil. I was taken by a friend to see a very elderly woman who, with her husband, had homesteaded the property and had collected, over an eighty-year period, numerous local vertebrate remains. The

main attractions were some "complete skulls with crystals in the eye sockets" that were displayed in her home. Complete skulls are nearly non-existent in my part of the country, and there was a possibility these would be donated to California Polytechnic State University. While walking through the yard, I saw huge slabs of rock that contained partial skeletons of extinct marine mammals, so common in our area. I proceeded to give a running commentary to the old woman. She snapped back that these were remains of dinosaurs. In my youthful exuberance, I told her why they were whale bones. My friend literally kicked me in the shins to bring me to a more aware state, but it was too late. The woman was irate and said we had seen enough of her possessions. We weren't allowed a glimpse of the skulls inside the house. I did not want to fail here in the Philippines because of a similar lack of sensitivity and tact.

The following day Laddie said a prayer (and, as far as I know, it was the only day he did so) and he began to assist in the excavation. To the best of my knowledge, Tony never bled on the fossil (an act that an Araneta, or a Fierstine, for that matter, would be loathe to do anyway). After two days of frantic digging, the fossil was excavated in several pieces, and each was placed in a protective plaster jacket. To our dismay only part of the head, paired fins and shoulder region were present in the rock. The vertebrae and tail were absent and, if fossilized, were some unknown distance away. In contrast to the prediction of the original spiritual medium, no remains of any associated human rider were found. Carpenters built three large crates from mahogany and packed the various pieces in banana leaves. Several days later the crates were trucked to Manila on the *last* vehicle to leave Pacific Farms this rainy season.

All went as planned. Our entire fossil collection arrived at our Natural History Museum in Los Angeles without mishap. Mary Odano, a fossil preparator, spent nearly two months removing the matrix and assembling the pieces of marlin together. She did an excellent job and its scientific value held up to my expectations. Dr. Edward Wilson and staff sorted and curated most of the invertebrate specimens and sent them to a Japanese specialist for study. The fish ear bones and the very tiny unicellular invertebrates *(foraminifera)* also have been sent to specialists.

The marlin specimen is now in my laboratory at the university. Every time I study it and, especially when I move it, I wonder if this is when the back pain comes. I think I would rather consult a medium than an orthopedic surgeon, except I don't know one here. So far, Laddie's prediction of no mishaps is correct. Usually I am prone to procrastination, but in this case I am quickly studying the specimen so that I can return it to the Philippines as soon as possible. I remember well that too few prayers were said and no blood was shed!

*Harry L. Fierstine is a Research Associate in the Vertebrate Paleontology section at the Natural History Museum and a professor at California Polytechnic State University, San Luis Obispo. He is an expert on living and fossil fish.*

## ADDENDA

The following letter recently has been received by the author from Dr. Johanna Resig at the Hawaii Institute of Geophysics (University of Hawaii at Manoa). She has been studying samples of unicellular invertebrates *(foraminifera)* sent her by Dr. Fierstine.

Dr. Harry Fierstine
Biological Sciences
California Polytechnic
State University
San Luis Obispo, CA 93407

Dear Dr. Fierstine:

In the meantime, I've noted that the marlin-bearing layer has a large amount of volcanic ash in it, which our petrologist, John Sinton, says is probably the result of an eruption of an arc-type volcano. Therefore, since the sample of the layer I've examined does not contain much material displaced from shallow water, I would propose that the preservation of the marlin is due to rapid burial under a rain of ash rather than a turbidite.

This leads us to the intriguing possibility that the fish did indeed die in an explosion, as visioned by the mystic, for some of those arc-type eruptions can be pretty explosive. Now all you have to do is find the primate bones!

Sincerely,
Johanna Resig

*Author and son prospecting for fossils along shore of Gayaman Island.*

*The neurocranium (braincase) from the fossil marlin was collected earlier by Dr. Araneta, Jr. and given to the expedition for study. The front of the specimen is to the right. The marlin is estimated to have weighed over 1,000 pounds and to have lived in the Early Pleistocene period (about 2,000,000 years ago).(Photography by photographic staff, Natural History Museum of Los Angeles County).*

# BOLIVIA: CROSSROADS OF A CONTINENT

by KENNETH E. CAMPBELL

*Photographs by the author*

The mornings are the worst. The hard ground, only minimally softened by foam padding, becomes unbearably hard after endless hours encapsulated within a warm sleeping bag. There is a strong urge to arise at first light, but the sub-freezing temperatures within the tent are only slightly above those outside. It becomes difficult to ignore the patches of ice that continue to form on the outside of the sleeping bag where the breath touches. On the campstove outside the tent the morning's coffee water waits, frozen into a solid block of ice.

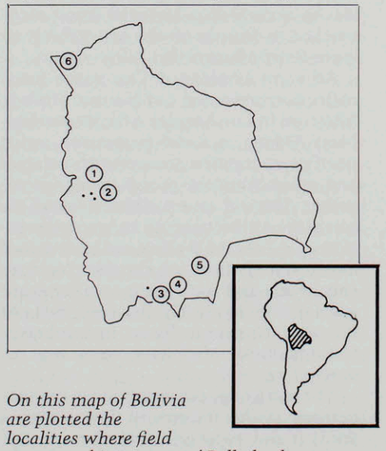
There is an almost perceptible start when at last the first sun breaks the horizon. Rapidly, the temperature begins to climb. Already, from various quarters up and down the valley, the faint voices of children and the barking of dogs can be heard as together they drive the families' sheep from their night corrals toward the open pastures on the sides of the mountains. There they will all pass the day. Within an hour after sunrise it is necessary to begin shedding layers of clothes, and by mid-morning it is already pleasantly warm.

So begins a day of field work in the altiplano of Bolivia.

The altiplano of Bolivia is a high plain lying between two great ranges of the Andes Mountains that run the length of the country. From Lake Titicaca in the north to the southern frontier with Argentina, the Western Cordillera of the Andes forms the frontier with Chile, while the broader Eastern Cordillera divides the country down the middle. Numerous peaks exceeding 6000 meters (about 20,000 ft.) break the horizon along both cordilleras. In Bolivia, the Eastern and Western Cordilleras of the Andes, that extend from Venezuela at the northern end of the continent to the very southern tip of Argentina, are found at their greatest distance from each other.

As the two mountain ranges were being elevated to their present altitude, sediments eroding from their steep slopes filled the basin between them to an elevation of almost 4000 m (13,000 ft.). Intermittently, active volcanoes added numerous layers of white ash to the sediments. Sometimes these ash layers reached five to seven m (sixteen to twenty-two ft.) in thickness, and they may be traced for miles. Numerous small sedimentary basins were also formed within the mountain chains themselves and later these too filled with sediments. If volcanic ashes are included as part of these sediments it is possible to date them by radiometric analyses and determine when during the formation of the mountains the basins were filled.

*Top: Looming over the outcrops at Salla, a nearby peak glistens with a fresh coat of snow. The snow had fallen the previous night, and by mid-morning it was gone.*




*On this map of Bolivia are plotted the localities where field crews working as part of Palbolus have searched for fossil vertebrates. The numbered localities are (1) La Paz, the largest city in Bolivia and the headquarters for Geobol and Palbolus; (2) Salla; (3) Quebrada Honda; (4) Tarija; (5) Nuapua; and (6) the Pando. An inset map shows the location of Bolivia in South America.*

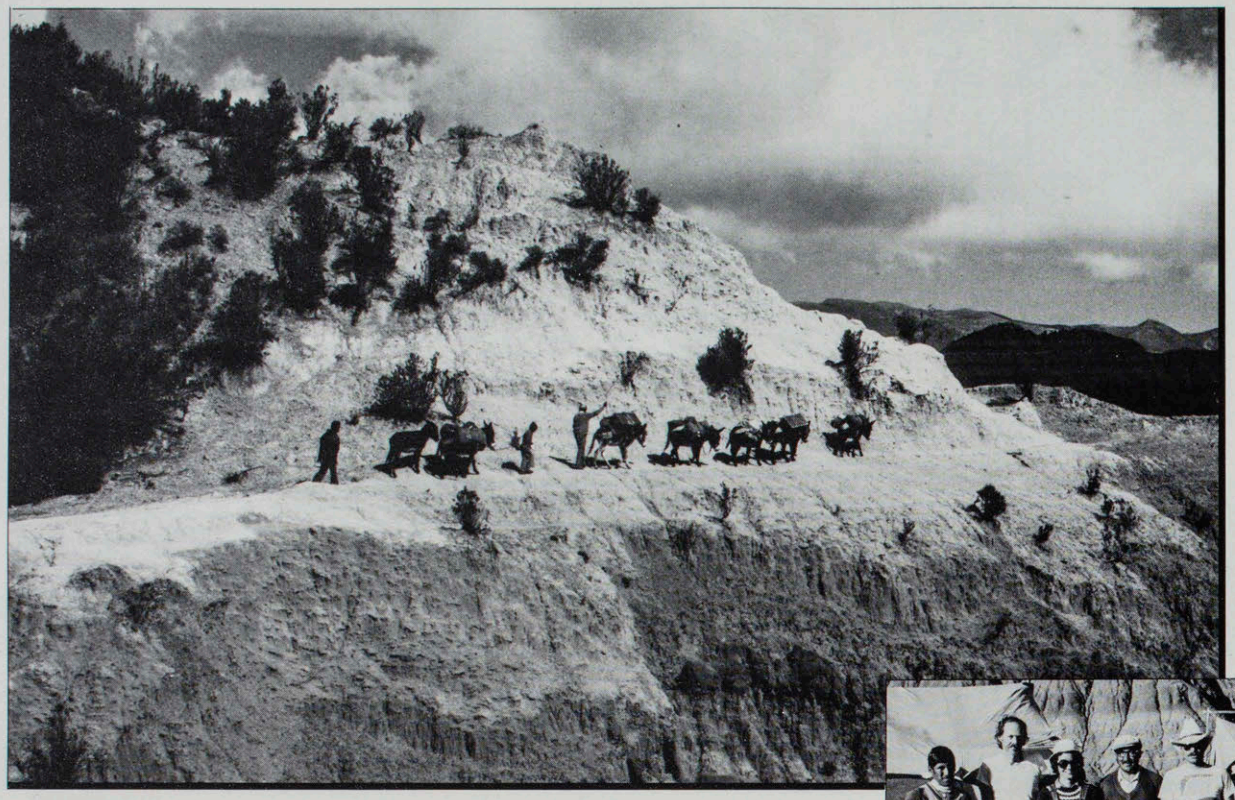
Within the sediments that underlie the altiplano and fill the smaller intermontane basins, and also within those sediments along the northern and eastern flanks of the Andes, were buried the bones of many, many different kinds of animals that have lived in South America during its long history. The bones of animals that lived tens of millions of years ago to those that lived only several thousand years ago are abundantly preserved in rocks of many different ages. Many of these animals are still unknown to science. It is the search for the fossilized bones of these animals that takes us to the altiplano and many other places in Bolivia, for they can provide information not only about the animals themselves, but also about the geological history of South America. Although the general outlines of that long history are known, the regional details and the timing of many noteworthy events are still mysteries. Perhaps most importantly, understanding the fossils and their history will allow us to better plan for the future.

One of the reasons that we are so interested in South America and its fossil faunas is because they are important to theoretical discussions in many fields of biology. South America and its faunas are often cited as showcase examples of several basic biological principles, such as speciation and evolution, competitive exclusion, population biology, ecology, biogeography, and many others.

To a research scientist, South America can be viewed as a giant laboratory. There, over a period of millions of years, an ingenious natural experiment was carried out. As with any good experiment, it seemed designed to answer specific questions, with many new questions coming up as the experiment progressed. If this had been an experiment designed by a research zoologist, three of the major questions it may have been designed to answer might have been the following. First, if you take two groups of animals, put them onto two different continents, and keep them separated for millions of years, how will they compare through time? Second, what might happen if selected foreign types of animals are introduced at intermittent intervals into one of these exclusive groups? And third, what would happen if, after tens of millions of years of separation, the two faunas are brought together and given the opportunity to mix?

The experiment can be said to have started during the latter portion of the Mesozoic Era, or Age of Dinosaurs, which covers that period of earth history between 240 and sixty-five million years ago. At the beginning of the Mesozoic, all of the continents of the earth were joined together as one supercontinent called Pangaea. About 200 million years ago, this supercontinent split into smaller land masses. The northern land mass, called Laurasia, eventually split into North America, Greenland, Europe, and Asia.

The southern landmass is called Gondwanaland. During the Cretaceous, Gondwanaland began splitting into the continents of South America, Africa, Antarctica, and Australia. By the end of the Cretaceous, or about sixty-five million years ago, South America had become an island continent. From then until almost the end of the Cenozoic, or Age of Mammals, South America remained an island. Surrounded by ocean waters, the mammalian faunas of South America evolved in isolation from all other faunas of the world. Not until near the end of the Pliocene, about two and one-half million years ago, would South America be connected by land to another continent. That connection was established by the forma-



*Burro trains were necessary to transport our gear to campsites at Salla. Here, the burros walk a narrow path cut into the side of the steep slopes by the local people.*

*The 1981 field crew in camp at Salla included, left to right, Teodoro, our chauffeur from Geobol; Dr. Ron Wolff, University of Florida; Dr. Annalisa Berta, Florida State Museum; Ing. Oscar Siles, Geobol; Dr. Bruce MacFadden, Florida State Museum; and the author.*

tion of Central America.

During the early and middle Miocene, about fifteen to twenty million years ago, a series of islands dominated by volcanoes stood where Central America is today. These islands grew in size and were gradually united into a more or less continuous land connection during the late Miocene and early Pliocene. Then, at or near the end of the Pliocene, the connection was completed when what we now know as the Isthmus of Panama rose above the ocean waters. South America's isolation of almost sixty million years ended, and its land animals were free to move into North America, and vice versa.

Prior to the establishment of the land connection through Central America there were a few additions to the mammalian fauna of South America. There were also a few notable "escapes" from the island's isolation.

The first known mammals that invaded South America after it became an island were the primates and, as you may have guessed, rodents. These two groups probably arrived in South America in the late Eocene, about forty million years ago. The oldest fossilized remains of these animals are found in slightly younger Oligocene rocks about thirty-five million years old. Both of these groups proliferated rapidly, forming many new genera and species, and they became an important segment of the South American fauna. It appears that no native South American mammals had evolved to fill the niches that the invaders came to occupy. Thus, there was no competition for space or food and the newcomers were able to establish themselves rather easily, and they spread into suitable habitats wherever they could find them.

About twenty-five million years later, as the islands that were to become Central America became larger, the distances between them became shorter. Soon, what are referred to as "island hoppers" began crossing from North to South America, and vice versa. The first known mammal to invade South America via this route was a member of the family Procyonidae. A fossil of this early invader has been found in rocks in Argentina that are about ten million years old. This was the first placental carnivore to live in South America. Raccoons are living procyonids, and they are quite adept and at home living near water. It is not surprising that an early relative of the raccoons was the first known "island hopper."

A short time later, geologically speaking, the first known "escapees" from South America reached North America. They were members of three different genera of small ground sloths, and they arrived in North America almost simultaneously about eight million years ago. Their fossilized remains have now been found from Florida to California. That they spread so far so fast indicates that they were quite successful in their new continent.

Once the land connection through Central America was completed, the "gateways" were opened, so to speak, and mammals from both continents flowed across the narrow land bridge. The mixing of the land faunas of the two continents began in earnest, and the last phase of the experiment was underway. And it has continued right up to recent times. Even the peopling of South America by groups of American Indians may be attributable to the existence of the Central American land bridge.

The mixing of the two continental faunas that began at the end of the Pliocene is referred to as the "Great American Faunal Interchange." Nothing similar to it is known to have occurred anywhere else in the world, and its consequences are still being debated. One point of debate centers around the fact that since the interchange began, many forms of South American wildlife have become extinct. A number of scientists think this wave of extinctions is a result of the competition posed by the North

*Strategically sited, the second campsite of the 1981 field expedition to Salla is completely surrounded by the colorful fossiliferous sediments.*

*The colorfully dressed women of Salla are always bundled in multiple layers of sweaters and shawls to ward off the cold.*

*A small gasoline generator provided power to furnish light at night, but the cold usually drove us rapidly into our sleeping bags.*

American invaders.

For example, with the single exception noted above, placental carnivores are unknown from South America prior to the time of the interchange. Instead, the mammalian carnivores living there were marsupial mammals. Marsupials are often considered to be less efficient as carnivores than placental mammals. So, the reasoning goes, they lost out in the competition for prey, or perhaps were preyed upon by the immigrant placental carnivores, and became extinct.

Similarly, the large South American herbivores such as glyptodonts, giant ground sloths, toxodonts and others are thought to have been driven to extinction as a result of the competition posed by their invading North American counterparts, such as the horses, camels, tapirs, and mastodons.

But there are many difficulties with the hypothesis that North American invaders brought about the mass extinctions of South American mammals. For example, why were such South American animals as the ground sloths and glyptodonts able not only to invade North America, but to survive and do quite well here for millions of years? And why did they become extinct in both continents only a few thousand years ago? Why did the horses that invaded South America become extinct as well as those that remained in North America, while the camels that invaded South America still survive but their relatives that remained in North America became extinct? How have the lowly opossum and armadillo been able to invade North America and thrive? Why did the saber-toothed cat become extinct on both continents? These questions and many others are still to be answered.

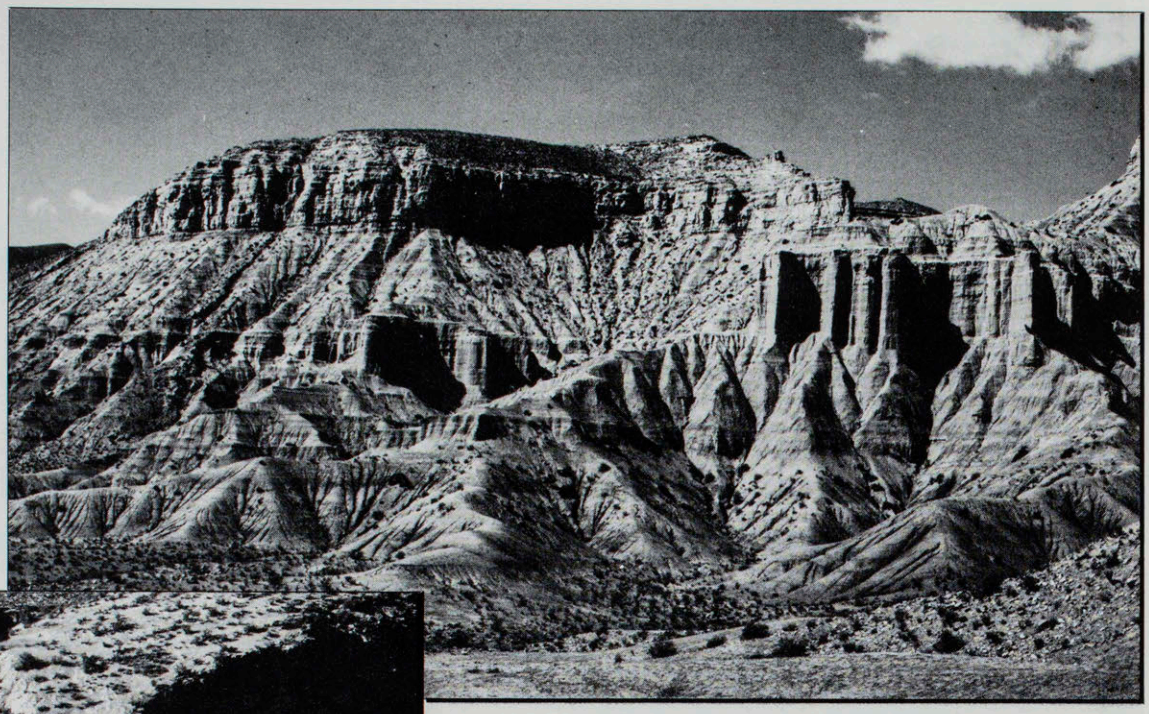
So it seems that although the question as to what would happen if two faunas from different continents were given the opportunity to mix appears straightforward, the answer and the actual result is very complex. It is the search for information that may lead to an answer to this question and many others about the evolution of South America and its faunas that takes us to that continent, and specifically to Bolivia.

A land of startling contrasts and breathtaking beauty, Bolivia is one of the least known countries in South America. Within the borders of this land-locked republic, which is nearly three times the size of California, can be found snow-capped mountains and high mountain plains, deserts and immense salt lakes, thorn-scrub and cactus forests, endless stretches of lowland swamps, and vast jungle forests. The climate of Bolivia is as varied as its terrain, and these two factors have combined to result in Bolivia's incredible number of diverse habitats. The complexity of Bolivia's modern fauna is also a reflection of its central location in the South American continent. The diverse modern fauna is still only poorly known, and to a natural historian, Bolivia is a paradise filled with undiscovered marvels of nature, living as well as fossil.

There are many reasons for traveling to Bolivia in search of fossil vertebrates. Although today almost one-half of the country is rugged high mountain terrain, these mountains are not very old. When South America first became an island continent during the Cretaceous, Bolivia was a low, flat-lying land. The region where today stand some of its highest mountains was under the ocean then, and sediments carried westward out of the mountains of Brazil were being deposited there. Tens of thousands of feet of sediment were deposited prior to and during the formation of the Andes. In many places these sediments preserved abundant examples of the vertebrates that lived in South America during and after its period of isolation.

The most famous and most thoroughly studied fossil deposits in South America are those of Argentina, at the southern end of the continent. The only major fos-

*The horizontally bedded rocks at Quebrada Honda are almost 350 m (1100 ft.) thick and contain abundant fossil mammals thought to be Miocene in age.*



*Our campsite at Quebrada Honda is placed in a stand of pampas grass. Conveniently, a spring-fed stream flows nearby.*

sil localities in South America outside of Argentina that have been studied in any great detail are found at the northern end of the continent, in Colombia. Being strategically located in the center of the continent, Bolivia may have preserved in its rocks portions of the faunas found in both Colombia and Argentina. By studying the faunas from Bolivia it may be possible to time the spread of North American immigrants as they moved from north to south.

To promote studies in vertebrate paleontology in Bolivia a cooperative international research program was established in 1977. Given the name Palbolus, for Paleontology-Bolivia-United States, the program includes participating scientists from the Servicio Geologico de Bolivia (Geobol), the Natural History Museum of Los Angeles County, the University of Florida, and other institutions. The participating scientists are all specialists in different aspects of geology and paleontology, and the purpose of Palbolus is to support new multi-disciplinary studies of known fossil sites and to explore for new fossil-bearing deposits. The fossil-bearing rocks of Bolivia are to be correlated with those of other countries through the use of faunal analyses and such sophisticated and relatively new techniques as paleomagnetic stratigraphy and radiometric dating of volcanic ashes. In 1978, Palbolus received the first of two National Science Foundation grants. Field expeditions were launched in 1978 and 1981, and others will be in Bolivia this summer.

One of the delightful aspects of field work in Bolivia is the variety of habitats where fossils can be found. When one tires of working in the cold, dry, dusty altiplano with its insufficient oxygen supply, it is possible to board a plane and in an hour begin setting up field operations in a hot, humid, tropical jungle. Taking advantage of this variety, expeditions working under the umbrella of Palbolus have collected fossils and carried out geological studies in numerous localities scattered throughout the country. This has also allowed us to study fossils in rocks of many different ages, which will be of some importance in researching changes in the faunas of Bolivia through time. It will help too in determining whether there existed major differences among faunas in different regions of the country.

In the altiplano of Bolivia we have worked primarily at two major, well-known sites that have produced large numbers of fossils. The most famous of the two is located high in the Eastern Cordillera, technically just outside the boundary of the altiplano. This site, called Salla after a nearby town, was discovered in 1962 by Professor Gaston Bejarano, a good friend and colleague and a strong supporter of science interests in Bolivia. Although I had visited the site during other visits to Bolivia, our first large-scale expedition to Salla was in 1981. At that time we were greatly aided in our search for fossils by the expert knowledge of the area of Dr. Carlo Villarroel, the sole professional vertebrate paleontologist in Bolivia. Later, with the field assistance of Ing. Oscar Siles, we were able to make detailed stratigraphic sections and collect rock samples for dating.

At an elevation of almost 4000 m (13,000 ft.), surrounded by the still higher snow-covered peaks of the Andes, Salla is a harsh environment in which to do field work. The biggest problem is that the air at that altitude just does not have much oxygen in it. While the native Indians are renowned for their ability to function normally at high altitudes, newcomers to the area find that even slow walks on level ground are sufficient to cause one to start gasping for breath. But

*This well preserved glyptodont jaw, about 18 cm (7 in.) long, illustrates the quality of the fossils found at Quebrada Honda.*

*Campsites on the Rio Acre were placed on any convenient sandbar. A simple lean-to was sufficient for the author, while others preferred to use a tent.*

*Ing. Raul Carasco of Geobol inspects a fossiliferous sandstone at the richest locality we found along the Rio Acre in 1981.*

to collect fossils it is necessary to scramble up and down steep slopes, carrying heavy packs of collecting gear, rock samples, and fossils. And the closest fossiliferous outcrops are a good two hours hike in from the nearest road.

To minimize the physical exertion as much as possible we establish camps deep in the valley. After working the area around one camp, we move on to the next. All camping and collecting gear, food, and water must be brought in and transferred from one site to another by burro train. This is always an exciting time, particularly the loading of the burros, because they can be called anything but tame, and they usually are!

Nights in the altiplano are stunning. Minutes after the sun goes down the temperature plummets, and usually within an hour it is near the freezing mark. But the stars! With almost no intervening atmosphere to dim their light, the stars fill the sky in incredible numbers. Of course, being in the southern hemisphere the familiar constellations are not to be seen, but it is a notable pleasure to view the Southern Cross.

Another aspect of life that is peaked by the thin air is what one hears. Voices, sheep bells, and the occasional banging of a pan carry for long distances, mixing with the crisp, clear tones of singing birds. It may seem strange, but familiar noises sound different in the altiplano.

Although working at Salla is very difficult, the rewards more than compensate for the troubles. The most famous fossil ever to come from this site is a monkey-like primate called *Branisella*. This is the oldest primate ever found in South America, and only a couple of specimens had ever been found. These had been found by the local people, so it was not known exactly where they came from. In 1981, Dr. Bruce MacFadden of the Florida State Museum found our first specimen, and for the first time it is possible to say exactly where in the hundreds of feet of section *Branisella* occurs. Now, when the dating of the rocks is completed, we will be able to say rather precisely when these first South American primates were fossilized. Of course, their actual date of arrival on the island continent of South America may have been much earlier. The next question is, how did they get there and where did they come from?

The rocks at Salla are thought to be Oligocene in age, or about thirty-five million years old. Although these rocks are now at an elevation of almost 4000 m (13,000 ft.), they were formed at a much lower elevation, probably closer to 500 to 700 m (1600 to 2200 ft.). They were brought to their present elevation with only a minimal amount of folding and faulting by the uplift of the Andes over the past ten to fifteen million years. These rocks are now being eroded away and their fossils are being exposed. Composed of silts and clays, the rocks weather rapidly, exposing new fossils during nearly every rain. Because it rains during only a few months of the year, there is insufficient moisture to allow much vegetation growth. As a result, the hillsides are bare and finding the fossils is relatively easy.

Salla is of particular interest to me because we have found there several specimens of fossil birds, which are my specialty. They are some of the oldest fossil birds known from South America, and they may shed some light on the evolution of that continent's avifauna.

Far to the south, near the frontier with Argentina, much younger fossiliferous rocks are found in the altiplano. This site, called Quebrada Honda after a nearby river, contains rocks that are late Miocene in age, or only about ten to fifteen million years old. It is a little easier to work at this site as we can drive to our main campsite, and we only have to pack in

*Imbedded in sandstone, this bird humerus from the Rio Acre is from a Miocene cormorant.*

*Surprisingly, high cliffs such as this are relatively common along the Rio Acre. About 30 m (100 ft.) high, this cliff displays almost the complete section that can be seen along the river.*

*While it is necessary to work in the Pando during the dry season, the low water levels in the rivers make traveling difficult. Here, the Rio Acre is filled with sandbars and uprooted trees.*

with a burro train when we are going to a particularly remote area of outcrops. Water is also available near camp, so we do not have to pack it in. This is a definite contribution to cleaner bodies and healthier spirits!

As at Salla, large collections of fossils have been collected from this locality. Samples of the rocks and volcanic ashes were also collected in 1978 and 1981, and these samples will allow us to precisely date these fossils. These specimens, both fossils and rocks, are currently under study by members of Palbolus. When completed, these studies will make it possible to correlate the fossiliferous rocks of Quebrada Honda with well-known localities in Argentina and elsewhere.

Scattered the length of the altiplano are numerous other sites that we have examined or briefly worked. Places like Ayo-Ayo, Umala, Corocoro, Vizchachani, Lachayani, Tupiza, and many others have provided small samples of vertebrate faunas. Less productive than Salla and Quebrada Honda, they have been temporarily overshadowed by the two larger sites. But their faunas are important, for they are all of different ages and each has a story to tell of a particular slice of time in Bolivian history.

My favorite place for collecting fossils is the Amazon jungle, and in 1981 we had our first visit to the Bolivian Amazon. This region is called the Pando, and elevations are only about 250 m (800 ft.) above sea level, which is quite a relief after working in the altiplano. I had worked previously in the Amazon of Peru with Dr. David Frailey, then of the University of Kansas, in expeditions sponsored by the National Geographic Society. Our field work in the Pando is an extension of that work into Bolivia.

Fossil collecting in the jungle is much different than fossil collecting in dry, semi-arid areas. Vegetation is everywhere, and the only places where rocks can be seen is in cliffs along the rivers. Exploration is also limited to the dry season when the rivers are low and it is possible to examine the outcrops. During the rainy season the rivers are usually five to eight m (sixteen to twenty-five ft.) higher than they are during the dry season.

Exploration is usually carried out by hiring a local guide with a canoe and simply traveling up and down the rivers. In Peru, we used inflatable rubber rafts for our work because they are much easier to handle in shallow water than heavy native dugout canoes, and future plans call for their use this coming year in Bolivia. In 1981, Ing. Raul Carasco of Geobol and I spent two weeks on the river Rio Acre, traveling in and living out of a motorized canoe. We found one exceptionally rich fossil deposit, but the fossils are preserved in a hard sandstone that makes collecting difficult. We also found numerous fossils at other places, collected wood samples for radiocarbon dating, and studied the geology of all major outcrops.

Field work in the Pando during the dry season is quite pleasant. It is not too hot, and there is always a cooling breeze blowing over the river. There is also an almost complete absence of mosquitos in this part of the Amazon. Fresh fish is readily available, if you have any luck with a line. At night, the canoe is tied up alongside a sandbar where the evening's camp is established. In the jungle, wood is always available for campfires, and the astounding numbers of insects, frogs, birds, monkeys, and other wildlife always create a myriad of background sounds. These, plus the usual absence of biting insects, always make the evenings an enjoyable time.

This work in the Amazon is producing the first true fossil faunas known for that vast area. Fossils have been found before in the jungle, but they were only frag-

*Most of the outcrops along the Rio Acre are cliffs of moderate height. During the rainy season, the river channel will fill to almost the top of the cliffs seen here.*

*In this overview of Nuapua, the gray sediments covering the flat surface are clays deposited from an ancient lake. These clays contain abundant fossils of frogs, birds, and mammals.*

*Perched on the top of a bluff, the small village of Bubuyo in the Pando is often shrouded in heavy morning fog.*

ments found loose on the banks of the rivers. They were not actually excavated from the rocks, so it is unknown exactly where they came from. As we have learned, fossils of at least two widely different ages are found in the rocks of the Rio Acre. The oldest fossils date from the Miocene, and are similar in age to those of Quebrada Honda. The comparison of these similarly aged fossil faunas at opposite ends of the country, one in the low jungle and the other in the high altiplano, will tell us much about how similar or varied the faunas of Bolivia were during the Miocene. These studies may also tell us something about how the faunas of Bolivia reacted in response to the formation of the Andes, which were just starting to be formed at the time these fossils were being deposited.

The youngest fossils found along the Rio Acre are less than 10,000 years old and were deposited since the end of the Pleistocene, or the last Ice Age. This discovery is particularly important because it indicates that in this region the forests of the Amazon jungle as we know them today may be only a few thousand years old. Much additional work will be required to determine the extent of these young fossil beds, but if they are widespread deposits, these studies will have broad implications. Such modern-day concerns as land-use planning, agricultural development, park planning, and many other areas of development may be affected.

The bountiful fossil deposits of the Tarija basin in southern Bolivia are perhaps the easiest deposits in the country to work. Completely surrounding the picturesque small town of Tarija, rich fossil sites are only minutes from the center of town. It is thus possible to stay in a pleasant hotel, dine in civilized surroundings, and commute to the site chosen to be worked on any given day.

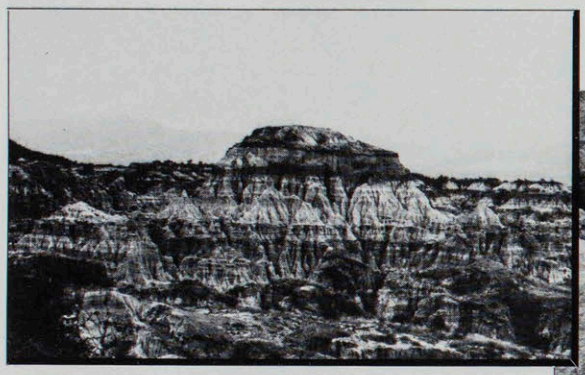
At an elevation near 2000 m (6500 ft.), usually warm and sunny, Tarija is a very pleasant place to work. It has a dry climate, excellent for the numerous vineyards that make Tarija the wine center of Bolivia.

The fossiliferous deposits are vast. They cover thousands of acres and are hundreds of feet thick. They date from the middle Pleistocene, and the oldest beds are about one million years old. These deposits were formed during the height of the Great American Faunal Interchange, and many mammals of North American origin are found at Tarija. These include such animals as horses, camels, mastodons, wolves, foxes, cats, and many others. By the precise dating of these deposits we will know the latest dates by which these animals reached this far south.

When the fossil beds of Tarija were first discovered, the fossils literally carpeted the ground in tremendous numbers. Large collections from this classic locality were made for museums all over the world, including the La Plata Museum in Argentina, the Field Museum in Chicago, and museums in Uppsala, Sweden and Paris, France. The only paleontological museum in Bolivia is to be found in Tarija, a testimony to the richness of the deposit. Today, as a result of the large collections made by expeditions of the past, the fossil collecting is not as productive as it once was. Numerous fossils are still to be found, however. It is just necessary to walk a little farther for them. And too, more concentrated effort is now being put into looking for small fossils, or microfossils, such as the remains of rodents. Microfossils were often overlooked in the early collections that amassed large quantities of big bones, although they are often more important than the larger fossils in terms of the information they may provide. They are certainly easier to carry out of the field.

*The human skeleton from Nuapua was excavated from the gully in the lower right hand corner. The gray lake clays are seen in the background.*

*The badlands of Tarija cover thousands of acres, and fossils may be found just about anywhere in the basin. In the background may be seen the mountains that surround the basin.*



*The carapaces of glyptodonts, that look something like giant turtle shells, are found quite commonly eroding out of the Pleistocene sediments of Tarija.*

The youngest site we have worked is called Nuapua. Located in the eastern foothills of the Andes, these fossiliferous deposits formed in a small basin beginning sometime after the end of the Pleistocene. Hence, these deposits are contemporaneous with the younger deposits found in the Pando. The lower beds are gravels and sands, indicating deposition by fast-flowing streams. The higher beds are layered clays that were deposited in an ancient lake.

Today, this region of Bolivia has a semi-arid climate. The vegetation consists of lots of thorn bushes, cacti, and other xerophytic plants. There is a lot of bare ground, and this helps make fossil collecting a little easier. Unfortunately, the outcrops are a fast-paced two hour walk from the nearest road, which limits the time that can be spent at the site during any given day. Logistical problems prevent the establishment of a more convenient camp.

Our most surprising find at this locality was part of a human skeleton. A study of the skeleton by Dr. William Maples of the Florida State Museum, a physical anthropologist, indicated that the skeleton was that of a female about fifty years old. Some of the bone scraps from the skeleton were dated by radiocarbon analysis, and from this we know that this early American died about 6500 years ago.

This find was surprising because we had thought the deposit was much older than it has turned out to be. Perhaps more surprising was the fact that we found in the same sediments the remains of giant ground sloths, glyptodonts, and horses, all animals that were supposed to have become extinct in South America a few thousand years earlier. Instead, they were living contemporaneously, around the same small lake, with the early Indians of Bolivia. Chemical tests have demonstrated that the human and the extinct animals were covered by the lake sediments at about the same time, so we know the human was not buried in recent times.

The presence of lake deposits in this presently semi-arid region is an indication of significant changes in the climate over the past several thousand years. One of the principal goals of future work in the region will be to correlate the climatic changes seen at Nuapua with those observed in the rocks in the Pando and elsewhere in Bolivia.

The efforts of the scientists participating in Palbolus have resulted in a number of notable discoveries, and if the program is able to continue there will assuredly be many more. The North American participants are grateful to the many Bolivian authorities in Geobol and other governmental agencies who have made our participation in this project not only possible, but a highly valued and treasured experience. We are eagerly awaiting the 1982 field season, for the most exciting thing about vertebrate paleontology is that you never know what strange, wondrous new animal may be found eroding out of the next rocks you may walk over.

*Recommended Reading:*

*Splendid Isolation* by George Gaylord Simpson. Yale University Press, 1980. This excellent volume written for the general reader summarizes our present knowledge about the history of South America and its faunas.

*Dr. Kenneth E. Campbell is Curator of Vertebrate Paleontology at the Natural History Museum of Los Angeles County. He works extensively in South America in pursuit of fossil birds, his favorite fossils. After a trip to Argentina in 1979, he brought to the Natural History Museum for research and exhibition the world's largest flying bird (*Terra, *Fall, 1980).*

(continued from page 2)

Pleurotomaridae family which represents the oldest, most primitive family of living gastropods. The exhibit is in the main foyer.

## LICHENS

The Botany Section is exhibiting a collection of the Museum's lichens, which will be shown for at least a year. To complement the real lichen samples pen and ink drawings of Gladys Baker are on display. Dr. Baker's drawings are made from samples sent her from the Richard E. Byrd 1934 Antarctic expedition. The show is in the small Botany gallery on the second floor.

## KIMBALL GARRETT JOINS STAFF

Dr. Ralph Schreiber, Curator of Ornithology, welcomed Mr. Kimball Garrett this spring as the Ornithology Department's new Collections Manager. Mr. Garrett, co-author of *Birds of Southern California—Statistics and Distribution,* is curating and caring for the 100,000 specimens already in the department's collection, as well as preparing and processing new specimens.

## RECENT ADDITIONS TO THE MINERAL & GEM COLLECTIONS

During the last half of December, 1981, over $600,000 worth of donations were received by the Mineralogy Section. Of these, approximately one-third are mineral specimens and two-thirds are gemstones or carvings.

The most significant minerals received are: a fine rubellite tourmaline crystal from Pala, California donated by Mr. Alan Caplan, an exceptional azurite specimen from the Touissite mine, Morocco donated by Mr. & Mrs. Albert Glickman and Mr. & Mrs. Jerry Lushing, and a beautiful aquamarine crystal from Minas Gerais, Brazil donated by Mr. & Mrs. Bernard Gelson.

Important gems donated include: a 220 carat morganite (anonymous), a 200 carat amethyst (Samuel Lynch), a 24 carat blue star sapphire (Mr. & Mrs. Jerry Lushing) and a tsavorite garnet necklace (Dr. & Mrs. John Parker). The finest carvings received are a 694 carat opal carved in a religious motif (Edward Fineman) and a 203 carat opal carving of two fish (Ted Hassen).

In addition to these donations, the Mineralogy Section spent over $25,000 on mineral specimens between mid-December and mid-March. Of these, the most noteworthy are an exceptional specimen of tourmaline on quartz from the Tourmaline Queen mine, Pala, California (Deutsch Fund) and a fine specimen of pyromorphite from the Bunker Hill mine, Kellogg, Idaho (Stuart Fund).

Some of the aforementioned acquisitions are already on exhibit in the Hall of Gems and Minerals. Others will be placed on display in the coming months.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